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SOIL CONSTRAINTS FOR SEPTIC TANK EFFLUENT ABSORPTION

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SURVEYS AND RESOURCE MAPPING BRANCH

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PREFACE

This manual provides a method for assessing the constraints imposed by existing soil conditions for conventional septic tank systems in British Columbia with discharges of less than 13 600 L/day (3000 gal/day). It explains how a soil functions in a septic tank effluent absorption field, why soil constraints should be determined before septic tank systems are installed, which properties of the soil are important to absorption field performance and how those properties can be evaluated and rated. The manual is oriented toward both protection of public health and the environment.

This publication is one of a series of manuals that describe methods used by the Surveys and Resource Mapping Branch in inventory or interpretive studies. It can be used either in conjunction with soil maps or as a guide to assessing on-site soil conditions. It is intended for use by personnel in planning, consulting and regulatory agencies when interpretive maps are unavailable or not of sufficient detail, as well as by Surveys and Resource Mapping Branch personnel when preparing interpretive maps.

It should be noted that the constraint evaluations described are not presently part of the legal process for obtaining approval for septic tank installations. All residential on-site ground disposal systems are controlled by the British Columbia Sewage Disposal Regulations published pursuant to the Health Act and the authority to apply them rests with the Medical Health Officer or his delegate.

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CHAPTER ONE
INTRODUCTION

As urban centres grow, people build homes in rural and urban fringe areas that are not provided with public sewer systems. In such areas, sewage disposal is normally accomplished by means of individual subsurface disposal systems (septic tanks and effluent absorption fields). Functioning properly, these systems are an effective, low cost method of disposing of household wastes. Absorption field failures however, can result in health hazards, environmental degradation, public nuisance and high maintenance and/or replacement costs. Success or failure of these systems (assuming proper installation, operation and maintenance) can be predicted from soils information by projecting logical consequences of the interaction of soil properties with sewage effluent applied at normal rates.

Interpretations such as this are carried out by pedologists across Canada as well as in the U.S.A. and other countries. A considerable amount of literature on specific aspects of sewage effluent absorption by soils and overall rating schemes has therefore been published. Most of the literature, however, is published outside of British Columbia, and while generally applicable, does not address unique British Columbia conditions. Often the overall rating schemes do not adequately explain the rationale behind the interpretations or the assumptions on which they are based. As well, the existing publications are conflicting on some points. Additionally many of these publications are not readily available in British Columbia.

This manual describes the role played by the soil in the effluent absorption process and shows how soil properties can be evaluated to determine their constraints for septic tank effluent absorption. The soil and terrain properties which are important to absorption field performance are discussed individually with regard to their effects and then are summarized in a rating table. Climatic influences are also discussed but not rated. A method is thus provided for assessing the constraints of existing soil properties for conventional septic tank effluent absorption fields in British Columbia.

CHAPTER TWO
THE SEPTIC TANK - SOIL ABSORPTION FIELD SYSTEM

The conventional septic tank-absorption field system typically consists of a septic tank and a distribution network which is made up of a distribution box and a series of distribution lines laid in trenches (Figure 1). After installation, the tank and pipe are covered with soil and the area is typically planted to grass.

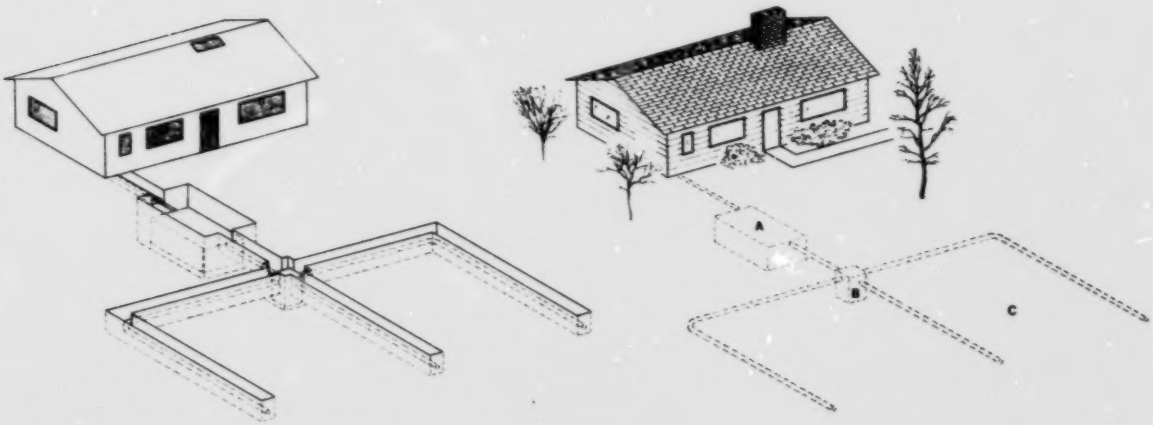

Figure 1. Example of a conventional septic tank-absorption field system showing septic tank (A), distribution box (B) and absorption field (C).

The primary purpose of the septic tank is to separate the liquid from the solids, grease and scum by sedimentation and flotation. Anaerobic digestion occurs in the tank, producing a sludge of decomposition products. These require periodic removal (pump-out) to maintain at least 80% liquid volume at all times. The liquid (effluent) flowing out of the tank has a high biological oxygen demand (BOD), contains many fecal organisms and considerable amounts of nitrogen and phosphorus (Table 1), and is therefore unsuitable for discharge into open water or onto the soil surface. The necessary final treatment of the

septic tank effluent is accomplished in the soil. Health hazards and/or eutrophication of water bodies occur when the effluent is discharged without this treatment.

Table 1. Mean and Range of Constituents in Septic Tank Effluents (after Tyler et al., 1977)

Constituent	Mean	Range
Biological Oxygen Demand (mg/L)	158	142-174
Total Suspended Solids (mg/L)	54	47-62
Fecal Coliforms (No./mL)	4210	2879-6158
Fecal Streptococci (No./mL)	38.2	20.1-72.4
Total Nitrogen (mg-N/L)	55.3	48.9-61.6
Ammonium-N (mg-N/L)	38.7	34.3-43.0
Nitrate-N, Nitrite-N (mg-N/L)	0.56	0.39-0.82
Total Phosphorus (mg-P/L)	14.6	11.4-17.7
Orthophosphate (mg-P/L)	11.5	10.2-12.8

The absorption field is intended to distribute the effluent uniformly throughout the area and allow contact with soil below the soil surface. It consists of a series of distribution lines laid in gravel beds in trenches greater than 30 cm wide and ranging from 55 to 80 cm deep. The lines are at least 180 cm apart and are normally parallel. A distribution box is used to distribute the effluent equally to the lines. The total length of distribution lines required is determined by the estimated daily sewage flow and the percolation rate of the soil (Government of British Columbia, 1975). The gravel placed below and around the distribution lines provides a medium through which the effluent can easily flow to the bottom and sidewall area of the trenches and helps to protect the pipes somewhat from frost and root penetration (Otis, Plews and Patterson, 1977).

CHAPTER THREE
THE ROLES OF SOIL IN ABSORPTION FIELD PERFORMANCE

Soil is defined as the naturally occurring, unconsolidated material on the surface of the earth that has been influenced by parent material, climate, macro- and micro-organisms, and relief, all acting over a period of time to produce soil that may differ from the material from which it was derived in many physical, chemical, mineralogical, biological and morphological properties (Canada Department of Agriculture, 1976). The unconsolidated material underlying the soil is referred to by pedologists as the soil parent material, a term synonymous with surficial material used in the geologic sense. Soil grades into parent or surficial material as soil forming processes become weaker with increasing depth from the soil surface. The lowest soil horizon in the vertical sequence (designated as a C horizon) generally is similar to the surficial geologic material.

In this publication, the term "soil" refers to the upper 2 m of unconsolidated material at the earths' surface. This is the material most important to effluent absorption. It is recognized that this zone includes the soil (in the pedologic sense) as well as the upper portions of the surficial material, but the characteristics of that material are very similar to those of the C horizon of the overlying soil. The properties of the entire zone are either described in, or can be inferred or extrapolated from, standard soil descriptions.

Soil characteristics, more than any other factor, determine the success or failure of septic tank absorption field performance (Huddleston, 1978; Tyler et al., 1977). If an absorption field is to function properly, the soil must do three things: it must first accept the effluent, then treat it and finally dispose of it (Figure 2).

Satisfactory acceptance and disposal requires that the effluent must always disappear into the soil without surfacing. The typical home-owner

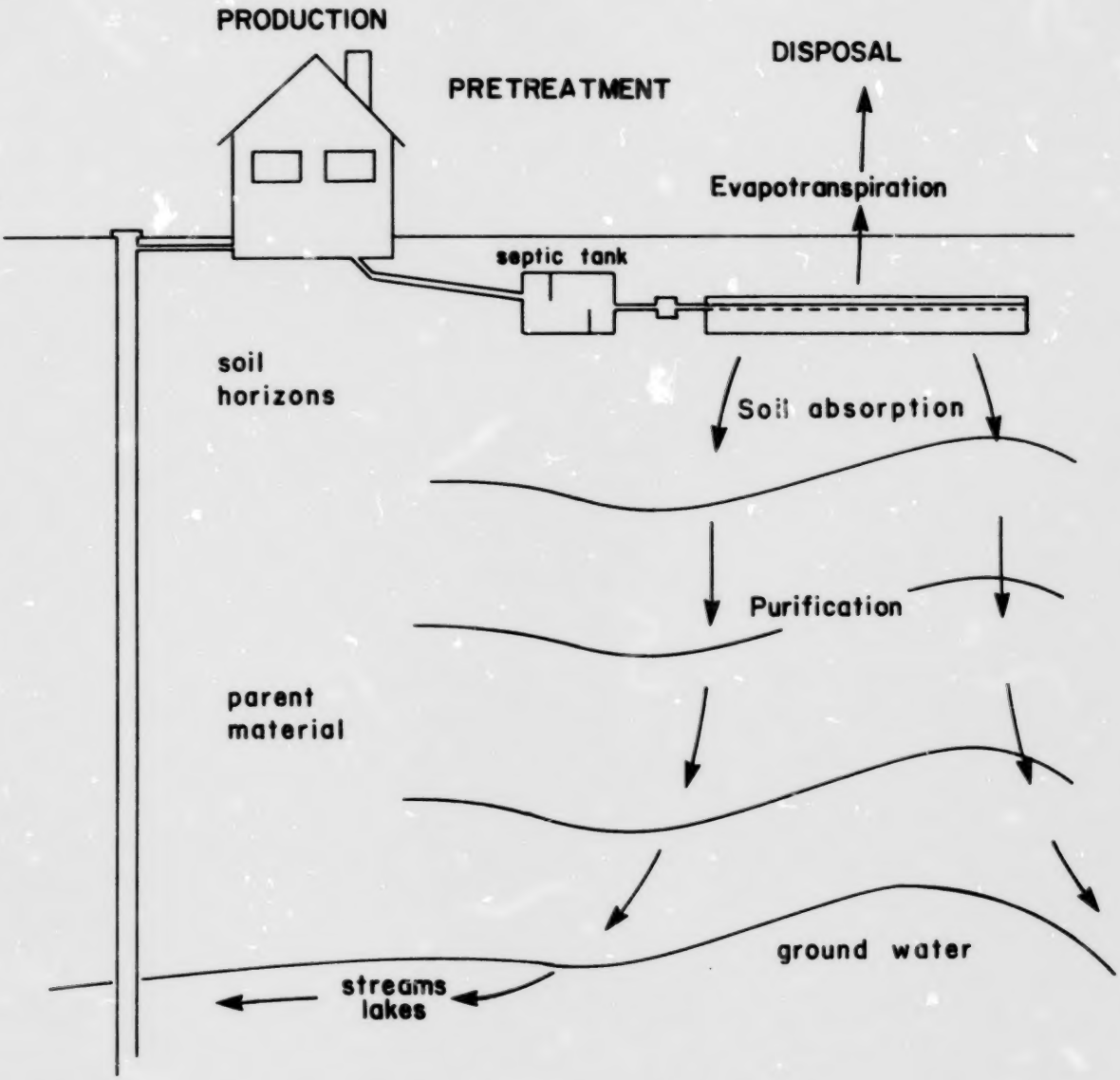

Figure 2. Typical septic tank-absorption field system recycling liquid wastes by soil absorption of effluent.

regards a soil as satisfactory as long as it can accomodate all the wastewater being generated without the effluent either rising to the soil surface or backing-up into the house. Failure of septic tank-aborption field systems due to effluent surfacing is readily observable, but (a) allowing excessive numbers of potentially pathogenic bacteria and/or viruses to reach private or public water supplies, or (b) causing increased nitrogen and phosphorus inputs to ground or surface water supplies resulting in eutrophication of surface water or potentially toxic nitrate levels in drinking water can also be considered as a failure due to lack of treatment. (Beatty and Bouma, 1973). Treatment failure can usually only be detected by groundwater analysis because treatment occurs underground and results from interrelated processes of filtration, absorption, and oxidation that reduce the amount of contaminants in the effluent (Bouma, 1974). Satisfactory acceptance, treatment and disposal can all be achieved given suitable soil conditions.

3.1 ACCEPTANCE OF SEPTIC TANK EFFLUENT

Acceptance of septic tank effluent is dependent on the permeability of the soil in the area of the trench-soil interface. Highly permeable soils readily accept effluent but soils with low permeabilities may not be able to accept the effluent as fast as it is generated. Permeability is determined mainly by the abundance, size and continuity of pores in the soil. Water and effluent can quickly move into and through large soil pores. Soils with a high proportion of large, continuous pores are therefore highly permeable and accept effluent readily. As pore size, abundance or continuity decreases, rates of movement into and through pores is correspondingly reduced and the rate of effluent acceptance is diminished.

The abundance, size and continuity of pores under natural conditions is largely a function of soil texture and structure. Texture refers to the relative proportions of sand, silt and clay in the soil while structure refers to the aggregation of the sand, silt and clay particles into larger units (peds). Large pores are commonly associated with coarse soil textures and/or

well developed soil structures while fine textures and/or poorly developed soil structures often result in smaller pores.

Construction practices can reduce pore size at the trench-soil interface and therefore reduce the effective permeability of the soil and its rate of acceptance of effluent. Excavation of trenches in medium and fine-textured soils when they are wet can result in smearing and compaction that destroys the natural soil structure and clogs pores with fine particles. The resultant loss of permeability can be directly responsible for septic system failure.

One of the greatest barriers to soil acceptance of effluent are slimy mats or crusts of organic materials that clog pores after the septic absorption field is put into use. These develop as a result of the deposition of organic matter in the soil pores by anaerobic organisms and the filtration of suspended solids from the effluent. In well aerated soils, aerobic organisms are active in breaking down these organic compounds. At any moisture/aeration condition, a dynamic balance exists between the activities of the two groups of organisms. Anaerobic conditions favor crust or slimy mat formation while aerobic conditions favor crust or slimy mat destruction (Bouma et al., 1972). Crusting and matting reduces the effective pore size and therefore the permeability of the soil and its rate of effluent acceptance. In extreme examples, crusts and mats have been shown to reduce flow to less than 1% of initial saturated flow (Tyler et al., 1977) and in very many cases they are responsible for the failure of absorption fields to adequately accept effluent. Maintenance of aerobic conditions in the soil is necessary to minimize the formation of organic mats and crusts that clog the soil pores.

Acceptance of effluent can also be hindered by saturated soil conditions due to naturally high water tables. These can either result from shallow depths to groundwater or from perched watertables above impermeable layers. Saturated soils can only accept water or effluent at a rate equivalent to that at which drainage is occurring.

3.2 TREATMENT OF SEPTIC TANK EFFLUENT

Although usually called the absorption field of the septic system, the soil does more than just receive and dispose of the effluent. It also purifies the effluent as the final step of treatment. Waste treatment in the soil is due to a combination of biological, chemical and physical processes. Given the time and the soil conditions necessary for these processes to occur, organic matter is broken down and the associated biological oxygen demand (BOD) reduced, pathogenic organisms are removed or inactivated, phosphorus is immobilized and some nitrogen may be removed. The effluent is then suitable for discharge into ground or surface water.

Septic tank effluent contains suspended (particulate) organic matter as well as soluble organic compounds. Removal of these organics from the effluent is important because once they reach open water bodies they are used by bacteria there as a food source. The utilization of the organic matter by the bacteria requires dissolved oxygen and so reduces oxygen availability to aquatic organisms. Under aerobic soil conditions (associated with moderate to rapid permeability), biological breakdown of organic material is promoted in the soil. This is accomplished by bacteria from the effluent as well as those that occur naturally in the soil. If growth conditions are suitable, (i.e. continued aerobic conditions and no nutrient limitations) the sewage-soil bacteria are able to biodegrade the whole complex of sewage organics including proteins, fats, carbohydrates, cellulose from kitchen and toilet tissues, pectin and lignin of vegetable wastes, hydrocarbons and many more. The end products of the decomposition are simple, soluble, mineralized compounds of nitrogen, carbon, phosphorus, sulphur, etc. such that the BOD of the effluent is reduced to a stable low level, suitable for disposal (Tyler et al., 1977).

Septic tank effluent contains significant numbers of various pathogenic organisms capable of causing human diseases. Some of these organisms are trapped in the crusting zone where conditions are very favourable for bacterial

growth. This results in the typically high numbers of bacteria which are found in the crusted area around the absorption trench. The numbers of bacteria and viruses in the soil are normally reduced to insignificant levels within a metre of effluent movement if aerobic conditions and unsaturated flow exist. This reduction with distance in the number of sewage bacteria in the soil, is a complex phenomenon resulting from filtering action, die-off due to limited nutrients, or die-off due to action of either toxic chemicals in the soil or the accumulated end-products of the bacteria themselves (Tyler et al., 1977; Brown, Slowey and Wolf, 1977). Saturated or nearly saturated flow in coarse-textured or highly structured soils (very rapid permeabilities) can, however, result in rapid transmission of bacteria and viruses for considerable distances before sufficient contact time occurs for them to be adsorbed onto soil particles or they die-off for other reasons. This poses a health hazard in areas where drinking water supplies could be contaminated due to their proximity to aborption fields in these soils (Tyler et al., 1977; Huddleston, 1978).

In most freshwater bodies, phosphorus is the key limiting nutrient for algae and aquatic plant growth (Lee, Rast and Jones, 1978). One of the phosphorus sources of greatest concern is domestic wastewater because it contains considerable amounts of phosphorus from detergents and human wastes. Most of the phosphorus is altered to soluble orthophosphate before reaching the soil. The potential of the soil to remove phosphorus from the effluent is mainly controlled by the mineralogy of the soil. Iron and aluminum oxides and clay minerals have relatively high capacities for phosphate sorption (immobilization) in neutral to acid soil systems. In neutral to alkaline systems, phosphates tend to be precipitated and immobilized by calcium. Most soils are therefore capable of removing much of the phosphorus from septic tank effluent unless the movement of effluent through the soil is too rapid for the reactions to occur effectively. This may occur in very coarse-textured soils or others where rapid transmission of the effluent through channels in the soil occurs (Tyler et al., 1977). Even so, precipitation of phosphorus can continue after entry into groundwater if groundwater movement is slow enough (Jones and Lee, 1979).

Nitrate levels in excess of 10 mg/L-N in groundwater are a health hazard when the water supplies are used domestically for drinking water (Andreoli et al., 1979; Tyler et al., 1977, Health and Welfare Canada, 1978). Nitrogen is also the second most limiting element in freshwater eutrophication (Lee, Rast and Jones, 1978). In many residential areas with septic tank-absorption field systems, a major contributor of nitrate to groundwater is the effluent from subsurface wastewater disposal systems. Nitrogen levels in septic tank effluent are high, mainly due to additions from human wastes. Because of anaerobic conditions in the septic tank, the nitrogen in the effluent leaves the septic tank as dominantly ammonia. Under continued anaerobic conditions in the soil, considerable ammonia can be removed from the effluent by adsorption onto soil exchange sites. Under aerobic soil conditions however, ammonia is quickly transformed to nitrate by soil bacteria through the process of nitrification. The nitrate is highly mobile and rapidly leaches into the groundwater. The density of the population contributing waste is therefore largely responsible for the amount of nitrogen from septic tank effluent entering the groundwater. The movement of groundwater then determines the dilution and therefore the concentration of nitrates in it.

3.3 DISPOSAL OF SEPTIC TANK EFFLUENT

Disposal of effluent is the last step of the effluent absorption process that must occur for successful operation of the septic tank effluent absorption field. Up to 1360 L/day (300 gal/day) is considered to be a typical amount of wastewater generated in a three bedroom house in British Columbia (Government of British Columbia, 1975). Disposal is considered adequate when all of the effluent generated disappears into the soil without surfacing or visibly appearing in nearby streams or ditches. Some of the water may be utilized by plants growing in the soil above the absorption field and a small amount is lost by evaporation from the soil, but most of it eventually flows through the soil into the groundwater and from there ultimately back into surface flows or water bodies (Huddleston, 1978).

As with acceptance and treatment, disposal depends mainly on soil permeability. The soil or underlying stratum must be sufficiently permeable to allow the effluent to be transmitted away from the absorption field. Slowly permeable soil layers, parent materials or bedrock can restrict the downward movement of effluent and therefore hinder effluent disposal. On slopes, the effluent may move laterally over restricting layers and result in effluent seeping to the surface downslope. Saturated conditions as a result of low permeability can also result in soil instability. High permeabilities generally do not present a disposal problem, although treatment may be inadequate.

High groundwater tables can also inhibit effluent disposal by maintaining saturated conditions in or below the absorption fields, thus restricting downward movement of effluent.

3.4 OPTIMAL SOIL CONDITIONS FOR EFFLUENT ABSORPTION

The preceeding discussion has shown that an absorption field best achieves its objectives of accepting, treating and disposing of septic tank effluent when the soil has: (a) permeabilities that are high enough to accept the effluent and transmit it away from the soil-trench interface, yet sufficiently low to allow purification of the effluent within a short distance as it moves through the soil; (b) aerobic conditions through which unsaturated flow occurs for at least one metre, thus ensuring breakdown of organic materials and reduction of associated biological oxygen demand, removal of pathogenic organisms, and immobilization of phosphates; and (c) no restrictions to subsurface flow which reduce the treatment zone to less than one metre or cause effluent (treated or not) to surface either at the site or downslope or in situations where it might cause or aggravate soil or bedrock instability. Meeting these conditions should assure successful functioning of septic tank absorption fields.

CHAPTER FOUR
SOIL PROPERTY CONSTRAINTS

Optimal soil conditions for effluent absorption have been discussed in Section 3.4. A number of soil properties, however, either singly or in combination, affect these conditions for successful acceptance, treatment and disposal of septic tank effluent.

Certain minimum soil and site properties are legally required in British Columbia by the Sewage Disposal Regulations (Government of British Columbia, 1975) for conventional septic tank-absorption field systems. These are:

1. Slope of the absorption field area to be less than 30%.
2. No impervious soil or bedrock or groundwater table within 120 cm (4 ft.) of the natural soil surface.
3. A percolation rate not exceeding 30 min/2.54 cm (30 min/in).

Special site specific designs may be authorized by the Medical Health Officer or his delegate (the Public Health Inspector) when these requirements cannot be met. The regulations present a two-class rating system - acceptable and unacceptable without modification.

Some soils, however, are more suitable than others, and some offer a greater potential for modification than others. It is often useful, therefore, to define several classes which express a range of constraints or limitations to use. Slight, moderate, severe and very severe constraints are terms used in this publication to describe increasing difficulties imposed by soil properties. The term "constraints" is equivalent to "limitations" as used in other publications (e.g. Kowall, 1979; Luttmerding, 1978; Coen et al., 1977; Lietzke, 1977; FAO, 1973; and USDA, 1971). Constraints is preferred since this term avoids the overly negative connotation of limitations. Construction in soils with slightly or moderately constraining properties is usually possible without major soil modification but soils with severely constraining properties

require major reclamation, special design or intensive maintenance for system development and operation. On-site disposal may be feasible in soils with very severely constraining properties, but even application of available innovative technology will generally not result in a completely satisfactory system. An absolute impossibility of on-site disposal is not implied by the constraint ratings, but a practical limit is suggested. Constraint class definitions are given below.

4.1 SLIGHT CONSTRAINTS

Slightly constraining soil properties are those which are well suited for effluent absorption and contribute to optimal soil conditions. Limitations due to these properties are minor and are easily overcome. Low construction costs and maintenance, and good performance can be expected from soils with slightly constraining properties.

4.2 MODERATE CONSTRAINTS

Moderately constraining soil properties are those which are acceptable but contribute to less than optimal soil conditions. These properties meet the minimum legal requirements (if applicable), but necessitate careful planning and design as well as more costly construction and maintenance than slightly constraining soil properties. Routine applications of available technology are generally sufficient to overcome moderate constraints.

4.3 SEVERE CONSTRAINTS

Severely constraining soil properties are those which contribute to major limiting soil conditions. These properties usually do not meet minimum legal requirements (if applicable) and successful operation of conventional absorption fields is usually not possible. Special innovative designs or construction may partially overcome severe constraints, but costs are likely to be excessive and overall performance less than desireable.

4.4 VERY SEVERE CONSTRAINTS

Very severely constraining properties are those which contribute to very severely limiting soil conditions. These properties do not meet the minimum legal requirements (if applicable) and, in most cases, modification of very severe constraints is economically impractical. A more technically advanced type of sewage treatment is generally required.

CHAPTER FIVE
SOURCES AND USE OF SOIL INFORMATION

Soil maps and reports, terrain (surficial geology) maps and reports, and on-site inspections are the main sources of information that can be used to evaluate soil constraints. The availability of maps and reports and the level of detail required will determine which information source is most applicable.

5.1 SOIL MAPS AND REPORTS

Soil maps and reports are the primary source of information for preliminary evaluations of soil constraints for septic tank effluent absorption fields. Soil surveys routinely examine most or all of the soil and site properties that are important to effluent absorption field operation. Soils are usually only described to a depth of about 1 m, but most of the relevant soil properties below that depth can be extrapolated or inferred from the lowest (C) horizon description. Exceptions are situations where a change in surficial material occurs below the soil description depth and, in these cases, reference to terrain maps and reports (see Section 5.2) is particularly useful. Soils with similar properties are grouped into units that are delineated on soil maps. The most important soil properties are indicated on the attached map legends and more complete soil descriptions are found in the soil reports.

Soil maps are usually classed as detailed or reconnaissance. General purpose, detailed soil surveys usually produce maps at scales of about 1:20 000 although special purpose surveys may have more detailed maps at scales of 1:10 000 or even 1:5 000. In detailed soil surveys, the soil properties for each map unit are defined within very limited ranges. Maps at a scale of 1:20 000 depict areas as small as 2 hectares (5 acres). Reconnaissance soil maps are usually at scales of 1:50 000 or 1:100 000 and the defined ranges of soil properties associated with reconnaissance survey map units are considerably broader than that of detailed survey map units. The smallest areas depicted on 1:50 000 scale maps are about 10 hectares (25 acres).

Soil maps have several limitations as sources of information for land areas as small as septic tank effluent absorption fields. Map delineations may include up to 15% by area of unidentified soils that are significantly different from those of the rest of the map delineation. This occurs due to scale limitations in relation to soil variation. Also, true soil boundaries may vary slightly from those shown on the soil map due to cartographic inaccuracies. These usually insignificant inaccuracies may be important when evaluating a land parcel as small as a building lot. These problems occur at all mapping scales, but the effects are minimized at more detailed map scales. Site specific investigations are therefore always recommended before actual absorption field approval or installation. Soil maps are, however, very useful at the planning or development approval stages where larger blocks of land are under consideration.

A complete listing of all soil maps and reports currently available for British Columbia is contained in the Ministry of Environment, Assessment and Planning Division 1981 Catalogue. Maps and reports are grouped by subject as well as regionally. The catalogue is available upon request from the Map Library, Planning and Resource Management Division, Ministry of Environment, Victoria, British Columbia.

5.2 TERRAIN (SURFICIAL GEOLOGY) MAPS AND REPORTS

Terrain maps and reports are also sources of information for preliminary evaluations of constraints for septic tank effluent absorption fields. Terrain maps are mainly concerned with the characteristics of the surficial deposits on which the soil is formed. Texture, origin of surficial material, surface expression and modifying processes are indicated on the maps and their characteristics are described in the legends and reports. Most properties affecting effluent absorption can be inferred from terrain maps but the properties are not indicated explicitly and the information is not as directly applicable as that given by soil maps and reports. Terrain maps can be used either as a supplement to soil maps or as a source of information when soil maps are unavailable.

Terrain maps are usually published at scales of 1:50 000 or 1:100 000, although 1:20 000 or larger scale mapping may be produced for special purposes. Map scale limitations similar to those described for soil maps apply to terrain maps.

A complete listing of all currently available terrain maps and reports in the Province of British Columbia is contained in the Ministry of Environment, Assessment and Planning Division 1981 Catalogue.

5.3 ON-SITE INSPECTIONS

The Sewage Disposal Regulations (Government of British Columbia, 1975) require digging or boring of observation pits to a minimum depth of 120 cm (4 feet) and percolation testing at each proposed drainfield site before application is made for installation permits. This is required regardless of the availability of soil or terrain maps and reports in order to ensure that the minimum legal requirements are met at the exact site where the absorption field is to be installed.

On-site inspections should also be conducted at the planning stages to provide soils data if information is either not available or is too general. This can be accomplished by digging and examining representative soil exposures throughout the proposed development area. An examination depth of 180 cm (6 feet) is recommended to ensure adequate observation of all relevant soil properties. Procedures for examining soils and criteria for recognizing and assessing soil properties are presented in the discussion of soil properties affecting effluent absorption (Chapter 6) and in Appendices A to J.

CHAPTER SIX
SOIL AND SITE PROPERTIES THAT AFFECT EFFLUENT ABSORPTION

A number of soil and site properties, either singly or in combination define the soil conditions for optimal effluent acceptance, treatment and disposal. In addition to those properties listed in Chapter 4 that define minimum legal requirements (slope, percolation rate and depth to water table, restrictive soil layers and bedrock), other soil properties including danger of flooding, soil drainage, stoniness, coarse fragment content, landscape position, soil texture, soil structure and soil chemistry as well as climate are also important to successful effluent absorption. All of these are discussed individually below in terms of their recognition, effects on effluent absorption and constraint ratings.

6.1 PERMEABILITY (PERCOLATION RATE)

Permeability relates to the ease with which liquids can pass through the soil. It depends on the amount, size and continuity of pores in the soil and on soil moisture content. In a saturated but freely draining soil, large continuous pores have the greatest capacity to conduct water or effluent. As the moisture content decreases, the large pores drain first while the small pores drain relatively more slowly. Each soil has its highest permeability when saturated and soils with a high proportion of large pores have higher saturated permeabilities than soils with a high proportion of small pores. Permeability is specific for each soil due to differences in pore size distribution and each soil has a range of permeabilities that vary with moisture content. Lowest permeabilities generally occur at low moisture contents. Exceptions are soils with significant contents of shrinking and swelling clays. These soils have large continuous cracks (and therefore high permeabilities) when dry, but the soil swells when wet, closing the cracks and thereby drastically lowering the permeability.

Permeability determines the rate at which effluent can move into and through the soil. In terms of costs and design requirements, soils with overall low permeabilities require larger absorption fields than soils with higher permeabilities. Even with very large absorption fields, slowly permeable soils may still not accept effluent as quickly as it is being generated. This results in saturated conditions in the trenches and possible surfacing of effluent. Effluent moves very quickly through soils which have very high permeabilities. Contact time for treatment of the effluent is shortened and insufficiently treated effluent may reach groundwater or surface water bodies. Optimal conditions for acceptance and treatment of effluent are provided by soils with intermediate permeabilities.

Permeability (hydraulic conductivity) can be measured in a number of different ways. These include crust tests, undisturbed tube or block sample tests, and tests employing in situ pumping, double tube or air entry permeameters (Anderson et al., 1977). A widely used indicator of soil permeability for septic tank regulation and design is the Standard Percolation Test. This is the method prescribed for use in British Columbia by the Sewage Disposal Regulations (Government of British Columbia, 1975). The percolation test does not measure hydraulic conductivity directly, but rather measures the rate of change in water level in a hole in the ground. The rate of change is dependent on the hydraulic conductivity of the soil, the shape and size of the hole, and the moisture content of the surrounding soil. Test results can vary due to differences in hole digging and preparation, difficulties in accurate measurement, differing degrees of soil saturation prior to measurement, and the changing hydraulic head as the water level falls in the hole (Peterson, 1980; Dear, Matelski and Petersen, 1969). Perhaps the largest weakness of the percolation test and all measurements of saturated hydraulic conductivity is that they do not predict how the soil will react to prolonged effluent loading. The rate of effluent movement into the soil may be reduced drastically over time by the formation of a clogging mat and liquid movement below the mat is usually through unsaturated soil (Bouma, 1971). The crust test has been proposed by Bouma et al.,(1972) as an alternative to percolation tests because

it can be used to predict flow rates under a range of unsaturated conditions. Crust tests and other unsaturated hydraulic conductivity measurements, however, are difficult to conduct and therefore are not suggested here for routine site evaluations. An appropriate use for the crust test is the determination of recommended loading rates for different soils as identified by soil surveys (Anderson et al., 1977). With no reasonably simple alternative, the percolation test continues to be favoured for individual absorption field design.

To avoid confusion in the following discussion, it should be noted that percolation rates are recorded in min/cm (min/in) while permeabilities are recorded in cm/hr (in/hr). Time versus volume is reversed in the two measurements and a high percolation rate is synonomous with a low permeability and vice versa.

There is considerable variation in the literature with regard to percolation rates that are considered optimal and acceptable. In British Columbia for example, a maximum percolation rate of 30 min/2.54 cm (30 min/in) for conventional absorption fields is allowed by the Sewage Disposal Regulations. No minimum rate is specified. A number of publications however, including Coen et al. (1977), Otis, Plews and Patterson (1977), Parker et al. (1977), FAO (1973), USDA (1971), U.S. Public Health Services (1972) and Ontario Ministry of Environment indicate that percolation rates as high as 60 min/2.54 cm (60 min/in) are acceptable and Converse, Carlile and Petersen (1977) recommend corrective measures for soils with percolation rates of 60 to 120 min/2.54 cm (60 to 120 min/in). Minimum percolation rates ranging from 0.5 min/2.54 cm (0.5 min/in) to 7.5 min/2.54 cm (7.5 min/in) are specified by Machmeier (1975) and the Ten-State Committee for On-Site Sewage Systems (1977) as quoted by Otis, Plews, and Patterson (1977) and by Parsons (1973).

Based on this review of available North American literature, the following ranges of percolation rates are recommended for the four soil constraint classes defined in Chapter 4. The range between 2.5 and 15 min/2.54 cm (2.5

and 15 min/in) is considered appropriate for the slight constraint class and is in agreement with most publications. The ranges between 1.0 and 2.5 min/2.54 cm (1 and 2.5 min/in) and between 15 and 30 min/2.54 cm (15 and 30 min/in) are considered appropriate for the moderate constraint class. The higher range of rates is within the limits allowed in British Columbia for conventional systems but requires somewhat greater precautions in design and construction. Contamination of groundwater is a possibility at the lower percolation rate, particularly when vertical and horizontal separations between drainfield and groundwater or surface water are minimal. Percolation rates lower than 1.0 min/2.54 cm (1 min/in) and between 30 and 60 min/2.54 cm (30 and 60 min/in) are assigned to the severe constraint class. Contamination of groundwater is probable at the lower rate. Very large conventional absorption fields or dual (alternating) absorption fields are likely required at the higher rate. Special designs such as mound systems are a possible alternative for soils with the high percolation rates. It should be noted that use of sites with percolation rates higher than 30 min/2.54 cm requires special authorization from a Public Health Inspector in British Columbia. Soils with percolation rates higher than 60 min/2.54 cm (60 min/in) are very slowly permeable and are assigned to the very severe constraint class. Use of these sites requires technology beyond the scope of this publication.

Percolation tests and other measurements of permeability are not routinely carried out during the course of soil surveys in British Columbia. However, soils are routinely grouped into perviousness classes as a general indication of relative permeability, percolation rate and infiltration rate. This grouping is inferred from soil properties rather than field measurement (Walmsley et al., 1980). Definitions of the three perviousness classes are given in Appendix A. Percolation rate values are not defined for these classes. The relationships between permeability and soil texture and structure are discussed in sections 6.9 and 6.10 respectively.

Permeability can also be roughly estimated from information on terrain maps. Sand or gravel textured fluvial, fluvioglacial and colluvial materials

will generally have relatively high permeabilities. Fluvial deposits with silt veneers, fluvioglacial materials consisting of silty sand or silty gravel and non-compacted morainal materials typically have medium permeabilities. Clay and silty clay lacustrine and marine materials and compacted (i.e. most) morainal materials (glacial till) tend to have low permeabilities.

Site-specific percolation tests are required in British Columbia by the Sewage Disposal Regulations on all proposed installation sites prior to permit application. A standard percolation test procedure is specified and is outlined in Appendix B.

6.2 TOPOGRAPHY (SLOPE)

Topography refers to the steepness and pattern of slopes. It is mainly a function of the process(es) by which the surficial material was deposited and later modified, or the configuration of the underlying bedrock.

Topography is a very important parameter to consider for several reasons. Firstly, the grade of effluent distribution lines must be nearly level to achieve uniform distribution. If surface slope gradients are more than a few percent, distribution lines must be laid perpendicular to the slope to maintain a nearly level grade as well as a relatively uniform depth. As slope increases, the difficulty (and therefore the cost) of distribution line installation increases to the point where slopes become too steep for mechanized construction. The problem is magnified on irregularly sloping land where contours cannot be followed by straight absorption lines. Secondly, the effluent tends to seep laterally downslope rather than to percolate vertically if layers of lower permeability are encountered. This may not cause serious problems in rural areas with low housing densities, but in urban subdivisions, the effluent is likely to seep into adjacent downslope absorption fields and increase the amount of effluent which must be disposed of there. This can result in saturated soil conditions and unsatisfactory treatment. Surfacing of partially treated effluent is likely under these conditions,

particularly if the slope gradient decreases downslope. On steep slopes, seepage of effluent from cut banks of streets is possible. The velocity of the effluent moving through the soil increases with increasing slope, thereby increasing the potential for the effluent to move further before sufficient contact time occurs for adequate treatment of the effluent.

Absorption field installations are routinely allowed on slopes with gradients to 30% by the Sewage Disposal Regulations in British Columbia. The degree of constraint increases, however, with increasing slope. There is good agreement in the literature that nearly level surfaces are best suited for effluent absorption fields and that slopes greater than 30% are very severely constraining. The 0 to 30% range has been variously divided into slight, moderate and severe constraint classes with limits at 8, 9 or 10% and 15 or 20% (Maynard, 1979 a and b; Kowall, 1979; Luttmerding, 1978; Coen et al., 1977; Lietzke, 1977; FAO, 1973 and USDA, 1971). Slope classes of less than 9% for slight, 10 to 15% for moderate, 16 to 30% for severe constraints and greater than 30% for very severe constraints are most applicable when using soil maps in British Columbia since these correspond with the topographic classes usually shown on the maps. However, a range of 10 to 20% for the moderate constraint class is perhaps more suitable when assigning ratings on a site-specific basis in the field or when using maps which indicate these slope classes.

Soil maps routinely indicate a slope class (or classes) for each map delineation. Slopes can also be estimated from topographic maps by measuring the distances between contours. Slope gradients can be routinely measured accurately and easily on a site-specific basis using a clinometer or Abney level.

6.3 DEPTH TO BEDROCK

Depth to bedrock refers to the thickness of unconsolidated material (both soil and surficial material) overlying bedrock. Depth to bedrock is an important consideration in effluent absorption because (1) it determines the

thickness of material available for effluent treatment and (2) impermeable bedrock may cause saturated conditions in the overlying soil which, in turn, restricts treatment and can result in the surfacing of partially treated effluent. On slopes, the effluent is likely to seep downslope along the surface of the bedrock and may surface at road cuts or in lower slope positions. In cases where the bedrock is permeable (e.g. jointed or fractured) the effluent may enter the bedrock and reach groundwater with little further treatment. Contamination of groundwater can then occur if the depth of the overlying soil is too thin for adequate effluent treatment.

There is good agreement in the literature (although most authors do not cite supporting research) that at least 90 to 120 cm of soil between the lowest level of pipe in the absorption field and the surface of the bedrock is necessary for optimal effluent purification (Maynard, 1980 a; Kowall, 1979; Parker et al., 1977; Otis et al., 1977; FAO, 1973; USDA, 1971; Bender, 1971). With a maximum trench depth of 80 cm allowed in British Columbia by the Sewage Disposal Regulations, a total depth to bedrock of 2 m or more is required for optimal effluent purification and a slight constraint rating. A minimum depth to bedrock of 120 cm (4 feet) is required by the Sewage Disposal Regulations in British Columbia. Because absorption field trenches must be between 55 and 80 cm deep, as little as 40 to 65 cm of soil is left for effluent purification. This thickness is considered minimal and will likely result in less than optimal treatment of effluent. A depth to bedrock between 120 and 200 cm is therefore considered to be a moderate constraint. A depth to bedrock between 60 and 120 cm is not sufficient to allow adequate purification of effluent unless fill is added to increase the soil thickness. This depth is considered to be a severe constraint since construction in fill is beyond the scope of conventional absorption fields. A depth to bedrock of less than 60 cm is a very severe constraint since very little, if any, natural soil is available for effluent purification.

Soil maps routinely indicate the occurrence of rock outcrops and map unit descriptions generally give average or ranges of depths to bedrock when bedrock

occurs within several metres of the soil surface. Terrain maps also indicate bedrock occurrence directly, while soil and surficial material depth is indicated by the use of "veneer" and "blanket" surface expression designations. Veneers are less than 1 m thick, while blankets are thicker than 1 m but still exhibit the influence of underlying material which is assumed to be bedrock unless otherwise indicated. Shallow depth to bedrock is easily observable during on-site inspections by digging holes. The presence of bedrock outcrops is often a good indication that bedrock is also likely to be close to the surface in adjacent soil covered areas. Bedrock outcrops are usually apparent on aerial photographs unless obscured by dense tree cover.

6.4 DEPTH TO OTHER RESTRICTIVE LAYERS

Layers or strata that are relatively impermeable (other than bedrock) may also occur in the soil. Such restrictive layers are due either to the characteristics of the surficial deposits or to soil forming processes. These include cemented layers such as duric horizons, carbonate cemented horizons, ortstein horizons and placic horizons, layers of clay accumulation (Bt horizons), and very slowly permeable parent materials.

Restrictive layers have varying constraints depending upon their depth, thickness and continuity. Ortstein and clay accumulation horizons, for example, may occur entirely within the upper 80 cm of the soil. In these cases, it will be possible to place absorption field lines below the restrictive layers where they have no effect on permeability. Restrictive layers such as ortstein or duric horizons may also be present but discontinuous and therefore may not cause the soil to be slowly permeable. While generalizations about restrictive layers follow, it should be noted that there are exceptions which will only be apparent during on-site investigations.

The effects of continuous restrictive layers which occur or extend below absorption field depth are similar to those of bedrock in that they limit the thickness of soil available for effluent treatment and also act as restrictions

to downward movement of effluent. They too can cause saturated soil conditions and effluent surfacing in the area of the absorption field or at downslope locations.

Since similar problems are caused by restrictive soil layers as by bedrock, similar depth limits for constraints should be applied. Accordingly, a depth of greater than 200 cm to a restrictive layer is considered to be a slight constraint, a depth between 120 and 200 cm to a restrictive layer is considered to be a moderate constraint, a depth between 60 and 120 cm to a restrictive layer is considered to be a severe constraint and a depth of less than 60 cm to a restrictive layer is considered to be a very severe constraint. A minimum depth of 120 cm (4 ft) to "impervious" (restrictive) layers is required for conventional absorption fields by the Sewage Disposal Regulations in British Columbia.

Restrictive layers, when present, are noted in soil descriptions in soil reports. When only soil maps are available, the presence of restrictive layers can usually be inferred from information contained in the map legend. The taxonomic soil classification indicates the presence of Duric, Placic and Ortstein horizons as part of the name (e.g. Duric Humo-Ferric Podzol). Similarly, Luvisolic soils always contain clay accumulation horizons (Bt's). Slowly permeable parent materials can be inferred from the texture and genesis of the parent materials which are indicated in soil map legends and on terrain maps. Medium and fine-textured (silt and clay) morainal, lacustrine and marine materials are generally slowly permeable. In general, these materials can also be assumed to be slowly permeable when no textures are indicated. The stratigraphic information shown on terrain maps indicates where these materials underlie contrasting (more permeable) surface materials.

The presence of restrictive layers in the soil may be indicated by percolation test results provided that adequate pre-saturation is carried out. In sloping situations, however, adequate pre-saturation may be difficult since the water may be seeping away downslope over the restrictive layer.

Restrictive layers can be identified on-site by examining the soil in observation holes. Each type of restrictive layer has its own diagnostic characteristics, but hardness (especially when dry) and/or density is common to all. Duric, placic and orstein horizons occur only in areas of moderately high to high rainfall and are most common in coastal areas in British Columbia. The other restrictive layers are common throughout British Columbia. Descriptions and diagnostic criteria for these layers are given in Appendix C.

6.5 DEPTH TO GROUNDWATER TABLE

Depth to groundwater table refers to the thickness of soil and surficial material betweeen the soil surface and the highest point to which the water table rises on an annual basis. No differentiation is made between perched water tables and true water tables since the effects on use are similar. Depth to groundwater is an important property to consider because in the absence of other restrictions, it determines the thickness of material through which unsaturated movement of effluent can take place. Treatment of effluent, particularly removal of pathogenic organisms, is not nearly as effective after the effluent reaches groundwater (Otis et al., 1977). Also, in extreme cases, a high groundwater table can physically interfere with the soils acceptance of effluent. This can cause untreated effluent to rise to the soil surface or back up through the septic tank into the house. The highest groundwater level of the year must be considered because most absorption fields are in use on a year-round basis and the most limiting condition determines the degree of constraint.

There is good agreement in the literature (although most authors do not cite supporting research) that at least 90 to 120 cm of soil between the bottom of the absorption field and the highest annual water table is required for optimal effluent purification (Guthrie and Latshaw, 1980; Maynard, 1980 a; Kowall, 1979; Parker et al., 1977; Otis et al., 1977; FAO, 1973; USDA, 1972). With a maximum trench depth of 80 cm as allowed in British Columbia, this means that a depth to the highest water table of about 2 m or more is required for

optimal effluent purification and a slight constraint rating. A minimum depth to water tables of 120 cm (4 feet) is required by the Sewage Disposal Regulations in British Columbia. Because absorption field trenches must be between 55 and 80 cm deep, as little as 40 to 65 cm of soil is left for effluent purification. This unsaturated soil thickness is considered minimal and will result in less than optimal treatment of effluent. A depth to water table between 120 and 200 cm is therefore considered to be a moderate constraint. A depth to the highest water table between 60 and 120 cm is not sufficient for adequate purification of effluent unless fill material is added to increase the soil thickness. This depth is considered to be a severe constraint since construction in fill is beyond the scope of conventional absorption fields. A depth to water table of less than 60 cm is a very severe constraint since very little, if any, unsaturated natural soil is then available for effluent purification.

It should be noted that although the depth to the water table is used here as a criterion to indicate soil saturation, the capillary fringe (zone of capillary rise of water above the water table) is also essentially saturated. Because effluent renovation is generally poorer under saturated soil conditions, the presence of an enlarged zone of capillary rise adversely affects effluent treatment. This can modify the interpretation of water table depth, particularly in fine-textured soils where capillary rise is most prevalent. In these soils, it is suggested that water table depths which are borderline between two constraint classes be assigned the more severe rating.

Descriptions of individual soils in soil reports usually give general ranges of depths to water tables although some variation between individual sites within map units is likely. Soil map legends also sometimes indicate water table depths or they can be inferred from other legend information. Soils that are imperfectly drained and/or soils which have a "Gleyed" modifier in their taxomic classification are likely to have water table depths associated with severe constraint ratings. Soils which are designated as poorly or very poorly drained and/or are classified as Gleysols or Organic

soils are likely to have shallow water table depths associated with very severe constraint ratings. Terrain maps generally do not indicate water table depths but the presence of high water tables can somtimes be inferred from the type of materials present. Active fluvial and organic deposits often have high water tables.

Water tables, if present within 200 cm of the ground surface, are readily apparent during the wettest times of the year in observation pits. The pits generally fill with water to a level coinciding with the water table surface. At other times however, the height of a fluctuating water table may be inferred from the elevation of adjacent water bodies in relation to the site or from soil characteristics such as colour. Gray and blue-gray (gleyed) colours result from chemically reduced iron, due in part to lack of oxygen in saturated soil. This indicates long periods of wetness. Brown, red-brown and yellow-brown colours indicate oxidizing conditions which are associated with well aerated, rarely saturated soils. Splotches of one of these colours in a matrix of the other is referred to as "mottles" and indicates periodic saturation. The depth at which mottles begin coincides generally with the maximum height of a fluctuating water table. Mottles are common above impermeable layers indicating a temporarily perched water table during wetter times of the year.

6.6 FLOODING

Flooding refers to inundation of the soil surface. In most cases where these conditions occur, absorption fields will not function since the soil is already saturated and unable to accept the effluent. Movement of untreated effluent with the flood water is likely and a serious health hazard is possibile. The soil often remains saturated for a period of time after surface waters recede and absorption field operation is impaired during this time.

Flooding is not explicitly considered by the British Columbia Sewage Disposal Regulations. There is however, good agreement in the literature (Kowall, 1979; Coen et al., 1977; Mitchell, Frick and Rourke, 1977; Parsons,

1973; FAO, 1973; USDA, 1971) that absence of any flooding is a requirement for a slight constraint rating. Some publications (Kowall, 1979; Coen et al., 1977; and Mitchel, Frick and Rourke, 1977) also indicate that absence of flooding is a requirement for a moderate constraint rating while others (Parsons, 1973; FAO, 1973; and USDA, 1971) suggest that rare flooding can be allowed for a moderate constraint rating. Occasional and frequent flooding are usually associated with severe and very severe constraints, respectively. Most publications do not assign frequency values to these descriptive terms. It is proposed therefore, that flooding frequency of less than once in 200 years should be considered as rare flooding and be the criterion for a moderate constraint rating. Flooding frequency between once in 20 and once in 200 years should be considered as occasional flooding and be the criterion for severe constraint ratings. Flooding more frequent than once in 20 years should be considered as frequent flooding and be the criterion for very severe constraints. The values of once in 20 years and once in 200 years correspond with criteria in floodplain designations by the Water Management Branch, British Columbia Ministry of Environment.

Floodplain mapping is being carried out by the Water Management Branch and where available, these maps represent the most accurate source of flooding hazard information. Soil maps and reports can also be used to approximate areas subject to flooding. Map unit descriptions in soil reports usually indicate which soils are subject to flooding. When not mentioned directly in reports or legends, flooding can generally be assumed to occur, at least occasionally, on all soils that have developed from fluvial deposits and which are classified as Regosolic (unless protected by dykes). Regosolic soils lack horizon development due to periodic disturbances or young age. On fluvial materials, these disturbances are usually due to flooding and associated erosion and deposition. Terrain maps indicate fluvial materials that are subject to flooding, by means of a superscript A on the material symbol.

Additionally, a number of on-site characteristics can be used in the field to estimate frequency of flooding. These include landscape position, presence

of flood debris on the soil surface, thickness of forest litter layers, type of vegetation, degree of soil development, and others. An example of how these characteristics have been used to estimate flooding frequency in northeastern British Columbia is given in Appendix D.

6.7 SOIL DRAINAGE

Soil drainage refers to the rapidity and extent of removal of water from the soil in relation to water additions. It is affected by a number of factors acting separately or in combination, including permeability, texture, structure, gradient and length of slope, water holding capacity and evapotranspiration rate. Six drainage classes are usually used to describe the relative ability of soils to cope with the water that is naturally added by precipitation, seepage or high groundwater. The classes range from "rapidly drained" in which the soil readily transmits any water that is added and seldom contains moisture in excess of field capacity, to "very poorly drained" in which the soil is unable to transmit water nearly as rapidly as it is added and is saturated for much or all of the year. It should be noted that some poorly and very poorly drained soils are highly permeable but cannot transmit the water due to high groundwater or excess seepage. Definitions of all drainage classes are given in Appendix E.

Soil drainage overlaps somewhat with permeability and depth to water table (discussed earlier). Soil drainage is important however because it tends to integrate several aspects of natural water movement through soil. It can be used to approximate the soils' ability to accept and transmit effluent, especially when permeability and water table data are either unavailable or of questionable reliability. Soils which transmit natural water easily, generally are able to cope with additional water from absorption fields. Soils which transmit natural water slowly in relation to additions, however, may not be able to cope with additional water.

Soil drainage is not considered as a separate factor by the Sewage Disposal Regulations in British Columbia, nor is it considered by several other

publications dealing with soil suitability for septic tanks. In those publications where it is considered (Kowall, 1979; Maynard, 1979 a and b; Luttmerding, 1978; Mitchell, Frick and Rourke, 1977; and Bender, 1971), there is good agreement that drainage in the well and moderately well drained classes is a slight constraint, imperfect drainage is a moderate constraint, poor drainage is a severe constraint and very poor drainage is a very severe constraint for effluent absorption.

These constraint ratings for the moderately well, imperfectly and poorly drained drainage classes are not, however, consistent with the constraints assigned to water table depths in Section 6.5. For example, the definition of of "imperfectly drained" (see also Appendix E) indicates a moisture excess for moderately long periods during the year and distinct mottling in the B and C horizons. This is more consistent with a depth to water table between 60 and 120 cm and a severe constraint rating than with a water table depth between 120 and 200 cm and a moderate constraint rating. Similarly, the "moderately well drained" class is more consistent with a water table depth between 120 and 200 cm and a moderate constraint rating. The "poorly drained" class is more consistent with a water table depth of less than 60 cm and a very severe constraint rating.

Rapidly drained soils have good effluent acceptance and disposal characteristics but often provide less than optimal treatment of effluent due to rapid transmittance of effluent. There is, therefore, a potential for groundwater or surface water contamination where the distance travelled by the effluent through unsaturated soil is short. In the absence of more definitive data, a moderate constraint is usually assigned to soils in the rapid drainage class. Site specific investigations, taking all factors into account may show that this drainage class warrants a more or less severe rating.

Accordingly, it is recommended that the <u>well drained</u> class be considered a <u>slight constraint</u>, the <u>rapidly drained</u> class and the <u>moderately well drained</u> class be considered as <u>moderate constraints</u>, the <u>imperfectly drained</u> class be

considered a severe constraint and both the poorly and very poorly drained classes be considered as very severe constraints.

Soil map legends and soil descriptions in soil reports routinely indicate soil drainage classes. In the absence of soil maps, some indication of drainage can be inferred from terrain maps. Organic materials are almost always very poorly drained. Floodplains and low lying fluvial terraces are often poorly or imperfectly drained due to periodically high water tables. Lacustrine and fine-textured marine deposits tend to be moderately well drained and morainal deposits are usually well to moderately well drained depending upon texture and site position. Fluvioglacial deposits, higher fluvial terraces, and colluvial materials are normally well to rapidly drained due to coarse textures. It should be noted that these are generalizations only and that numerous exceptions occur.

In the field, soil drainage is best observed in test pits. Rapidly and well drained soils are characterized by relatively bright reddish or brownish colours with no evidence of mottling within the upper metre of soil. Moderately well drained soils often have faint to moderate mottling in the lower soil (below 70 cm) which indicates some periodic moisture excess in the lower horizons. Imperfectly drained soils usually have distinct to prominent mottles between about 50 and 100 cm from the soil surface indicating seasonally high water tables at these depths. Poorly and very poorly drained soils have mottling and/or gley colours close to the soil surface and are saturated for long periods. More detailed diagnostic characteristics are given in Appendix E.

6.8 COARSE FRAGMENT CONTENT AND STONINESS

Coarse fragment content refers to the percentage by volume of materials greater than 2 mm in size which are contained in the soil. Stoniness refers to the relative proportions of stones (coarse fragments >15 cm in diameter) on the soil surface. High contents of coarse fragments in the soil hinder

construction of the absorption field and reduce the effective soil volume since they do not help to treat effluent. Stones on the surface hinder construction of the absorption field and reestablishment of suitable vegetation. The magnitude of the problem increases with both the relative proportions and the sizes of coarse fragments and stones.

Coarse fragment content and stoniness are not considered in the Sewage Disposal Regulations in British Columbia. Most publications dealing with soil suitability for septic tank effluent absorption, including Kowall (1979); Luttmerding (1978); Converse, Carlile and Petersen (1977); Mitchel, Frick and Rourke (1977); Parsons (1973); FAO (1973); and USDA (1971) do, however, consider stoniness and/or coarse fragment content as a significant factor affecting use. When coarse fragment content is considered, less than 20% content is considered to be a slight constraint, 20 to 50% content is considered to be a moderate constraint and greater than 50% coarse fragment content is considered to be a severe constraint for effluent absorption. No further subdivision is made for very severe constraints. Stoniness is rated slightly differently by the authors but in general, stoniness classes 0 to 2 (up to 3% stones on the soil surface) are considered to be slight constraints, stoniness class 3 (3 to 15% stones) is considered to be a moderate constraint, stoniness classs 4 (15 to 50% stones) is considered to be a severe constraint and stoniness class 5 (greater than 50% stones) is considered to be a very severe constraint.

Coarse fragment content and stoniness are usually described in soil reports and may be included on soil map legends. Terrain maps indicate coarse fragments when known, as part of the texture by means of the following terms: pebbly, cobbly, bouldery, gravelly, rubbly and blocky. The sizes and shapes referred to by these terms are indicated on terrain map legends. Coarse fragment content can be estimated visually in the field in observation pits or measured more accurately by sieving. Stones on the soil surface are best estimated visually in the field.

6.9 SOIL TEXTURE

Soil texture refers to the relative proportions of sand, silt and clay in the less than 2 mm sized fraction of the soil. Textural classes with standard limits (see Appendix F) are used to describe soil texture. A table correlating soil texture classes commonly used in pedological soil inventories with the Unified system of texture classes and classes used by the American Association of State Highway Officials (AASHO) is included in Appendix G.

Soil texture does not directly have a major influence on soil constraints for effluent absorption, but rather, is an important factor that influences soil permeability. It is useful for estimating permeability when actual measurements are not available and can be used to support or question percolation test measurements. Coarse-textured soils have relatively large spaces (pores) due to a high proportion of sand sized particles and thus tend to have high permeabilities. Medium and fine-textured soils have relatively small spaces between the particles due to high proportions of silt and clay sized particles. Moisture moves through these small spaces much more slowly and so these soils tend to have lower permeability values. Soil texture can also indirectly affect phosphorus removal. It has been reported that very coarse-textured soils (sand and gravel) are least capable of removing phosphorus from effluent and that phosphorus can move up to 5 times as far in clean sands as in finer textured soils (Tyler et al., 1977). It has also been stated that the potential of a soil to remove phosphates from effluents is controlled by the soil mineralogy rather than the particle size (Jones and Lee, 1979). This tends to indicate that the lower ability of coarse-textured soils to remove phosphates is related to the low retention time associated with the high permeability of these soils rather than directly to the particle size. One problem related directly to soil texture is the susceptibility of soils with significant clay contents to compaction, smearing and puddling during construction when moist or wet. Otis, Plews and Patterson (1977) estimated that as little as 25% clay can cause significant problems in this regard.

Moderately coarse and medium-textured soils (sandy loam, loam and silt loam) are most likely to have permeabilities which qualify them for a slight constraint rating. Moderately fine textured soils (sandy clay loam, silty clay loam and clay loam) usually have lower permeabilities which are associated with moderate constraint ratings. These soils also require care in construction to avoid compaction and smearing. Coarse-textured soils (loamy sand) are likely to have high permeabilities and thus a moderate constraint rating. Fine-textured soils (silty clay, clay, sandy clay and heavy clay) are likely to have very low permeabilities and therefore severe or very severe constraint ratings. These soils are also quite susceptible to compaction and smearing. Very coarse textured soils (sands and gravels) are generally very highly permeable and have severe constraint ratings. It should be noted that these groupings are not completely definitive since soil structure (see 6.10) also has a significant influence on permeability, particularly when finer textures are involved. Texture and structure should both be considered in estimating the relative permeability of soils.

Texture or a range of textures is always indicated on soil map legends and/or in soil descriptions in soil reports. Textures often change with depth due to soil forming processes (e.g. clay translocation) or parent material variation. An average texture may be indicated, or in more detailed descriptions, texture may be given by soil horizon. All textures at and below absorption trench depth should be considered. Texture is also indicated on terrain maps by means of a modified version of the Wentworth Grade scale which has been standardized for use in British Columbia (see Appendix H). Soil texture can be determined during on-site inspections by "hand-texturing" as outlined in Appendix I.

6.10 SOIL STRUCTURE

Soil structure refers to the aggregation or arrangement of primary soil particles into secondary units or peds. The peds are characterized and classified on the basis of size, shape and degree of distinctness (see

Appendix J). Soil structure is not in itself a major property determining soil constraints for effluent absorption, but together with soil texture is an important factor influencing soil permeability, particularly in finer textured soils. Soils with well developed and distinct peds are likely to have well formed and continuous macropores which can conduct effluent fairly quickly. Soils with poorly developed or massive structure have indistinct peds which tend to result in poorly defined channels and a predominance of micro-pores through which movement of effluent is slow.

Most publications do not consider soil structure as a potential soil constraint when rating soils for effluent absorption systems. An exception is Parsons (1973) and the groupings below are based on his ratings. Soils with granular and subangular blocky structures are most likely to have permeabilities associated with slight constraint ratings. Blocky, columnar, prismatic and platy structures are likely to be associated with lower soil permeabilities and therefore represent moderate constraints. Massive and single grained structures are likely to be associated with low and very high permeabilities respectively and therefore represent severe constraints. As stated previously, soil texture (see Section 6.9) should also be considered when estimating the relative permeability of soils.

Soil structure is often indicated in soil reports and legends. Structure can be determined in the field by examining the soil in observation pits. The diagrams and criteria in Appendix J are the usual guide for determination of soil structure.

6.11 SOIL CHEMISTRY

Chemical properties of the soil which may significantly affect effluent treatment include cation exchange capacity (CEC), organic matter content, iron (Fe) and aluminum (Al) oxide content and calcareousness. Consideration of chemical properties is particularly important in the retention of bacteria and viruses, phosphates, and ammonium nitrogen (NH_4^+) in soils which are only

marginally suited for effluent absorption due to high permeabilities or shallow soil depths.

Bacteria and viruses behave as charged particles and can therefore be adsorbed by soil particles through electrostatic attraction. Similarly NH_4^+ can be adsorbed if not previously nitrified to nitrate (NO_3^-). The CEC is a measure of the ability of soil to adsorb positively charged entities (cations). Soils with high CEC's can be expected to remove bacteria, viruses and NH_4^+ from effluent more effectively than soils with low CEC's. Clay minerals and the organic component in the soil are largely responsible for the cation exchange capacity.

Phosphate ions form relatively stable surface complexes or precipitates with oxides and hydrous oxides of Fe and/or Al in neutral to acid soils and with calcium (Ca) in neutral to alkaline soils. The amount of immobilization is a function of the Fe and Al or the Ca content in the soil.

Definitive criteria have not been established for assigning constraint ratings on the basis of chemical characteristics or adsorption capacities. In general though, it can be stated that high levels of Fe and Al oxides and Ca compounds in the soil will enhance phosphate retention and that high CEC values will enhance bacteria, virus and NH_4^+ removal.

Representative chemical data is sometimes given in soil reports. When not reported, some indication of the relative abundance of Fe, Al, Ca and organic matter can be gained from soil horizon designations in soil descriptions and from the soil taxonmic classification. Soil horizons designated as "Bf" or "Bhf" (Podzol soils) contain relatively high amounts of Fe and Al oxides, while horizons designated as "Bm" (Brunisol soils) often have moderate Fe and Al oxide contents. Soil horizons designated as "Cca" or "Ck" contain high amounts of Ca. Fine-textured (see Section 6.9) soils tend to have higher CEC values than coarse-textured soils due to higher clay contents. Horizons designated as "Bt" also have accumulated significant amounts of clay and thus have a

correspondingly higher CEC. Soil horizons designated as "Ah", "Bh", or "Bhf" will have moderately high organic matter contents. Accurate site-specific values for all of the above requires laboratory analysis.

6.12 CLIMATIC INFLUENCES

Climatic variables which may significantly affect septic tank effluent absorption are form (rain vs. snow), distribution and total amount of precipitation, temperature regime and wind pattern. Precipitation determines the amount of moisture (excluding seepage and high groundwater) which is added to a soil naturally. Temperature regime and wind pattern influence potential evapotranspiration, depth of frost penetration and snowmelt. Climatic influences are most important when considering soils with low permeabilities where intense and prolonged precipitation or high moisture additions due to snowmelt can overload the hydraulic capacity of the soil and lead to absorption field failure.

No definitive criteria are available for rating climatic influences other than that an indicator of the possible susceptibility of soil to hydraulic overloading due to natural moisture is soil drainage (see Section 6.7). However, based on the maximum field size specified in the British Columbia Sewage Disposal Regulations for a 3 bedroom house, it is estimated that the soil beneath the absorption field must have at least an effective, long-term permeability of 0.6 cm/day (4 cm/week) just to dispose of the amount of wastewater generated on site (1360 L/day). The preceding assumes that the effluent is being distributed evenly throughout the entire area occupied by the field. This is usually not the case since effluent tends to concentrate around the trenches and therefore the effective permeability must be somewhat higher.

The 4 cm/week effective permeability figure is only presented as an amount for comparison with precipitation and snowmelt additions. According to Environment Canada (1970) statistics, the total December precipitation in the Okanagan Valley (Kelowna) averages less than 1 cm/week. In the Fraser Valley

(Abbotsford) by comparison, the average total December precipitation is over 5 cm/week, while on the west coast of Vancouver Island (Tofino), December precipitation averages over 10 cm/week. These values, together with the 4 cm/week effluent addition, indicate that in December, absorption fields in Tofino and Abbotsford, on average, must respectively dispose of 3 and 2 times the amount of water as do absorption fields in Kelowna. Similar differences can result from deep snow accumulations melting rapidly in spring and can have significant implications for soils with marginal permeabilities.

Potential evapotranspiration also varies substantially among locations in British Columbia and can be a factor in assisting disposal of soil moisture additions by septic tank-absorption field systems. Most absorption fields in British Columbia, however, are located under lawns, gardens or other landscaped areas which are irrigated in summer and the positive effect of evapotranspiration on efffluent disposal is largely lost.

Depth of frost penetration is not a problem in most of British Columbia. Studies in the United States as reported by Otis, Plews and Patterson (1977) have shown that carefully constructed systems will not freeze if kept in use, even when frost penetration reaches 1.5 m in areas adjacent to the drainfield. Areas of permafrost should be avoided however, since the permafrost will initially prevent downward moisture movement (i.e. it is a restrictive layer). Later, due to raised temperatures by the effluent, melting of the permafrost will result in uneven settling and disruption of the effluent distribution lines.

Statistics relating to the climate of British Columbia are available from the Climatology Unit, Waste Management Branch, British Columbia Ministry of Environment.

CHAPTER SEVEN
SUMMARY OF CONSTRAINT EVALUATIONS

Eleven of the thirteen properties discussed in Chapter 6 are summarized in Table 2 where the range assigned to each of the four constraint classes is indicated for each property. Soil chemistry and climatic influences do not have definitive limits and so are not included. The table provides a quick reference to the constraints for effluent absorption imposed by soil properties.

7.1 EVALUATING SOIL CONSTRAINTS

To evaluate the constraints for effluent absorption caused by individual soil properties, determine under which constraint class in Table 2 the value or class of the property occurs. For example, a percolation rate of 10 min/2.54 cm falls in the 2.5-15 min/2.54 cm range and therefore is a slight constraint. Similarily, a 25% slope is in the 15-30% range, and is therefore a severe constraint and an S5 stoniness class is a very severe constraint.

In evaluating constraints for effluent absorption of the soil as a whole, it is first necessary to determine the constraint classes for all of the soil properties indicated in Table 2. The soil can then be evaluated as having all of the moderate, severe and very severe constraints indicated by this property evaluation. For example, a soil inspection may indicate the following information: percolation rate of 8 min/2.54 cm, 20% slope, depth to bedrock of 200 cm, no restrictive layers, no groundwater within 200 cm, no flooding, rapidly drained, 65% coarse fragments, stoniness class 3, sandy loam texture, and subangular blocky structure. Individual evaluation of these properties indicates slight constraints due to percolation rate, depth to bedrock, depth to restrictive layers, depth to groundwater, flooding, texture, and structure; moderate constraints due to drainage and stoniness; and severe constraints because of topography and coarse fragment content. This soil is therefore

Table 2. Soil Constraints for Subsurface Septic Tank Effluent Absorption

CONSTRAINT	CONSTRAINT CLASS [1]			
Soil or Site Property[2]	Slight (1)	Moderate (2)	Severe (3)	Very Severe (4)
Percolation Test Rate (Permeability) (B)	2.5 - 15 min/ 2.54 cm	15-30 min/2.54 cm or 1.0 - 2.5 min/ 2.54 cm	30-60 min/ 2.54 cm or <1.0 min/2.54 cm	>60 min/ 2.54 cm
Topography (T)	0-9% slopes	10-15% slopes	15-30% slopes	>30% slopes
Depth to Bedrock (R)	>200 cm	120-200 cm	60-120 cm	<60 cm
Depth to Other Restrictive Layers (D)	>200 cm	120-200 cm	60-120 cm	<60 cm
Depth to Groundwater (X)	>200 cm	120-200 cm	60-120 cm	<60 cm
Flooding (I)	none	rare (<1 in 200 year interval)	occasional (between 1 in 20 and 1 in 200 year interval)	frequent (>1 in 20 year interval)
Soil Drainage (W)	well	moderately well, rapid	imperfect	poor, very poor
Coarse Fragment Content (G)	0-20%	20-50%	>50%	-
Stoniness Class (P)	S0-S2 (0-3% stones)	S3 (3-15% stones)	S4 (15-50% stones)	S5 (>50% stones)
Soil Texture[3] (S)	sandy loam, loam, silt loam	silt, sandy clay loam, silty clay loam, clay loam, loamy sand	silty clay, clay, sandy clay, heavy clay	-
Soil Structure[3] (C)	granular, subangular blocky	blocky, columnar, platy, prismatic	massive, single grained	-
Soil Chemistry	See discussion on pages 37 to 39.			
Climatic Influences	See discussion on pages 39 to 40.			

1. See pages 12 to 14 for definitions of constraint classes. Abbreviations for constraint classes are given in brackets.

2. See Chapter 6 for complete discussion of the effects on use of each factor and rationale behind the ratings. Abbreviations for properties are given in brackets.

3. Criteria not completely definitive. See also discussion on pages 34 to 37.

evaluated as having severe constraints due to topography and coarse fragment content and moderate constraints due to drainage and stoniness. The appropriate sections of Chapter 6 could be referred to for discussions of the implications of these moderate and severe constraints.

The basic procedure is the same whether using site-specific information (as in the above example) or using information from soil and terrain maps and reports. It is important to note, however, that the precision and reliability of constraint evaluations change as the level of detail and the reliability of the basic information changes. Evaluations based on site-specific information are the most reliable because each property is accurately determined and evaluated. Evaluations based on map and report information may not be precise because ranges in some properties may correspond to more than one constraint class. For example, the slope may vary between 10 and 30% in a map polygon and this range corresponds to both moderate and severe constraints. Also, soil and/or terrain descriptions may not always adequately define all of the properties which are of interest and they must then be inferred or omitted from the evaluations. Shortcommings such as these do not negate the value of making constraint evaluations based on maps and reports; they simply substantiate the need for final on-site investigation after the preliminary evaluations based on map and report information are made.

It should be noted that these constraint evaluations only indicate the nature and severity of problems related to septic tank effluent absorption that are associated with each soil. Value judgements as to the relative suitability of one soil versus another are left to the user, taking into account the implications of each constraining property (Chapter 6) and knowledge of local conditions. Methods of evaluating soil suitabilities are discussed further in Chapter 8.

7.2 PRESENTATION OF CONSTRAINT RATINGS

When several soils are being evaluated, the results are usually presented in either tabular or map form. Both formats have been used in British

Columbia. The nature of the study usually determines which approach is most suitable.

7.2.1 Tabular Presentation

Soil constraint evaluations are commonly presented in tabular form, particularly in general purpose studies where constraints or limitations for a number of different land uses are considered. Tables are easier to include in reports and are less time consuming to prepare than maps. Therefore, it is common to have one map showing the areal extent of soil map units and a series of tables, one for each type of interpretation (e.g. soil constraints for effluent absorption fields), showing the constraints of the soils in those map units. This approach, illustrated in Figure 3 and Tables 3 and 4, is particularly suited to presenting the results of evaluations which are based on existing maps since no additional map preparation is required.

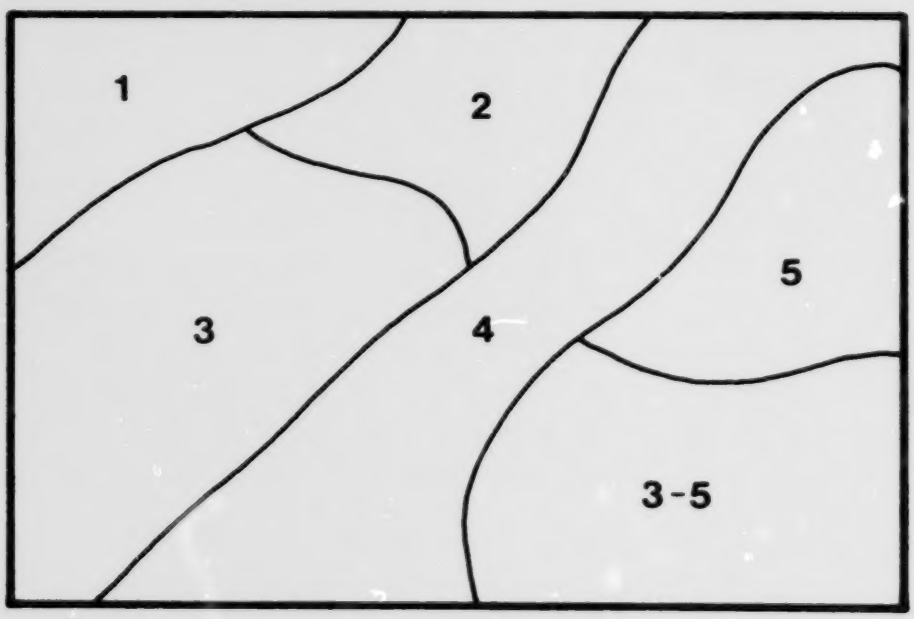

Figure 3. Example of soil map.

Table 3. Relevant Properties of Soils Shown on Map in Figure 3

SOIL PROPERTIES											
Map Symbol	Percolation Rate (min/2.54 cm)	Topography (Slope)	Depth to Bedrock (cm)	Depth to Restrictive Layers (cm)	Depth to Groundwater (cm)	Flooding Frequency (Years)	Soil Drainage	Coarse Fragment Content	Stoniness Class	Soil Texture	Soil Structure
1	10	40%	50	not present	not present	no flooding	well	75%	S2	sandy loam	subangular blocky
2	5	12%	150	not present	> 200	no flooding	well	40%	S2	loam	subangular blocky
3	25	5%	> 200	not present	> 200	no flooding	well	10%	S1	silt loam	subangular blocky
4	10	5%	> 200	not present	> 200	no flooding	well	5%	S1	loam	subangular blocky
5	15	2%	> 200	not present	75	10	imperfect	5%	S0	silt loam	subangular blocky

Table 4. Example of Constraint Ratings in Tabular Form

Soil	Constraint Class and Properties	Symbols
1	very severe - topography - depth to bedrock severe - coarse fragment content	4TR 3G
2	moderate - topography - depth to bedrock - coarse fragment content	2TRG
3	moderate - permeability	2B
4	slight	1
5	very severe - flooding severe - depth to water table - drainage	4I 3XW

Each of the soils (numbered 1 to 5) shown in Figure 3 is described in terms of its relevant soil characteristics in Table 3. The results of the constraint evaluations based on these properties are indicated in Table 4. It is preferable to show all of the constraining properties (other than slight constraints) because the implications of the constraints are cumulative. Properties not indicated can then be assumed to be slight constraints. Constraints may be written out in full or abbreviated as indicated. Symbols for each constraint class and constraining property are given in Table 2.

It should be noted that one map polygon on the example map is designated as 3-5. This indicates that this polygon contains both soil 3 and soil 5. Accordingly, portions of the area have constraints corresponding to soil 3 and the remainder has constraints corresponding to soil 5. Complexes such as this are common on some soil and terrain maps due to scale limitations (the individual soils occupy such small discrete areas or are so intermixed that they cannot be shown separately on the map). More detailed mapping or on-site

investigations are needed to determine more precisely the areal extent of the constraints in this map polygon.

7.2.2 Presentation on Maps

Map presentations of constraint evaluations often are easier to use than tabular formats because the constraints are indicated directly in the map polygons. There is then no need to cross-reference between tables and a map. This approach is preferred when interpretations are only being made for one or a few uses so that the resulting number of maps is manageable. An example of a map presentation of constraint evaluations is given in Figure 4. The map polygons and ratings correspond to those of Figure 3 and Table 4, but the ratings are now shown directly in the polygons. For simplicity of presentation, only the constraint class of the most severely constraining property(s) is usually shown and the number of constraining properties

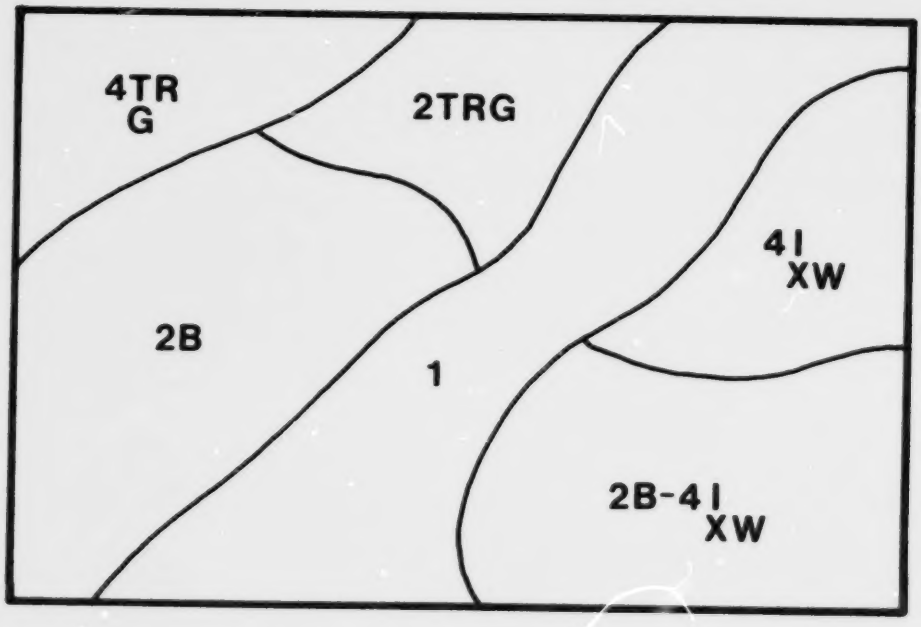

Figure 4. Example of constraint map.

indicated for each constraint class symbol is limited to a maximum of three. Constraints at a less severely constraining level may be shown if three constraints are not already indicated. Such a lesser constraint(s) is shown on a lower line. Thus for Soil 1, the severe constraint due to coarse fragment content is indicated on the lower line. Similarly for Soil 5, severe constraints due to depth to water table and drainage are indicated along with the very severe constraint due to flooding. The map polygon containing the complex of two soils contains a two component symbol indicating the presence of two soils with differing constraints. A decile on the line above the constraining property symbols may be used to indicate proportions of each of the soils.

CHAPTER EIGHT
SOIL SUITABILITY

The publication to this point has discussed and shown methods of presenting constraint ratings for individual soil properties that affect successful effluent absorption. These ratings indicate the nature and severity of problems related to effluent absorption which are associated with soil properties, but do not make direct judgements as to the overall suitability of one soil in relation to another. It is often necessary to make such judgements, however, especially when allocating areas to different uses such as in the planning process.

8.1 SUITABILITY BASED ON THE MOST CONSTRAINING PROPERTIES

The simplest rating of soil suitability is on the basis of the most severely constraining soil properties. A soil with all properties at the slightly constraining level has good suitability, a soil with one or more moderately constraining properties and the remainder slightly constraining has medium suitability, a soil with one or more severely constraining properties has poor suitability and a soil with one or more very severely constraining properties has very poor suitability. Constraining properties still should be indicated for the suitability rating so that comparisons can be made among soils in the same suitability class (e.g. comparing a soil with medium suitability due to moderately constraining topography with a soil having medium suitability due to both moderately constraining drainage and flood hazard). This approach differs very little from simply presenting constraint ratings as described in Chapter 7 and has been widely used in the past by Surveys and Resource Mapping Branch personnel and others. Presentation formats are similar to those described in Sections 7.2.1 and 7.2.2.

8.2 SUITABILITY BASED ON NUMERICALLY WEIGHTED CONSTRAINTS

It is readily apparent that the most suitable soils are those in which all of the soil properties fall into the ranges corresponding to slight

constraints. It is also apparent that the more properties a soil has that fall under moderate, severe or very severe constraints, the less suitable that soil is for effluent absorption. Accordingly, a second method of rating soil suitability assigns a numerical value to each constraint class. Each soil property receives the value of the constraint class that it falls under and the numerical values are then totaled for each soil. For example, numerical values of 0, 1, 2 and 4 can be assigned to slight, moderate, severe and very severe constraint classes, respectively. Using this approach, the five soils used as examples in Tables 3 and 4 have scores of 11, 3, 1, 0 and 8, respectively. These scores can be directly used to the rank soils as to their relative suitability, or the range of scores can be arbitrarily divided into three, four, five or as many suitability groups as desirable.

The numerical values of 0, 1, 2 and 4 are suggestions only and can be modified to suit the needs of any particular study. The values suggested imply that two moderately constraining properties are equal to one severely constraining property and that two severely constraining properties are equal to one very severely constraining property. These numbers also imply that a constraint value for one soil property is equivalent to a similar constraint value for another soil property.

8.3 SOIL SUITABILITY BASED ON UNEQUAL NUMERICALLY WEIGHED CONSTRAINTS

A variation of the above approach is to assign different numerical values to different properties within the same constraint class. This allows greater flexibility for taking into account local objectives, conditions and costs. For example, constraints due to depth to groundwater could receive different numerical ratings depending upon whether the area is served by community water systems or whether wells are used. Similarly, constraints due to high percolation rates (low permeability) could receive different numerical ratings depending upon whether lots can be made large enough to accommodate alternate absorption fields or whether prohibitive land costs result in minimal lot sizes. Assigning varying numerical values to constraints requires knowledge of

local objectives and conditions. It is therefore impractical to suggest such values on a province-wide basis. The soil potential system which has been introduced in the United States is similar to this variable weighting approach and is being applied on a county by county basis (Guthrie and Latshaw, 1980). Presentation of results can be in tabular or map form similar to the formats discussed in Sections 7.2.1 and 7.2.2 above.

8.4 OTHER SUITABILITY EVALUATIONS

Several other soil suitability evaluation and/or presentation approaches can also be used, particularly if visual impact in presentation is desired. The first approach is to overlay single factor (constraint) transparencies with shades of gray corresponding to degrees of constraint imposed by that factor. The darkest map areas in composite then represent land areas with poorest suitability. Another similar approach is using varying densities of cross-hatching or other screening. Coloured maps with green, yellow and red for good, medium and poor suitabilities can also be useful for presentation.

The objectives of the study will determine whether it is sufficient to simply indicate the nature and severity of individual soil property constraints or whether it is necessary to determine suitabilities as described previously. Constraint evaluations are probably most useful when examining problems in specific areas while suitability ratings are perhaps more useful when determining relative suitability over large areas.

CHAPTER NINE
FURTHER WORK AND RESEARCH REQUIRED

This manual briefly presents the principles of soil behavior in relation to sub-surface septic tank effluent disposal and applies them to specific soil properties so that soils can be evaluated with regard to their constraints for conventional septic tank effluent disposal systems. No research was conducted as background to the preparation of this manual and many of the references cited do not present specific research results to substantiate their interpretations. The class limits as presented are therefore somewhat arbitrary and can perhaps be further refined if more studies of absorption field performance under various soil conditions are conducted.

This manual is primarily concerned with soil constraints for conventional absorption field systems. Much of British Columbia has soils with severe and very severe constraints for conventional systems because of a variety of factors. There is, however, increasing pressure for new housing development on these lands and a need to develop alternate systems to satisfactorily overcome these constraints (other than relying on costly sewer systems). Development of satisfactory alternate systems to overcome specific constraints can help to alleviate the wastewater disposal problems on lands that are currently poorly suited for septic tank effluent disposal.

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APPENDIX A
SOIL PERVIOUSNESS CLASSES
(from Walmsley et al., 1980)

Soil perviousness classes refer to the potential of a soil to transmit water internally, and are inferred from soil characteristics such as structure, texture, porosity, cracks, organic matter content, and shrink-swell properties. They are closely related to measures of permeability, percolation rate, and infiltration rate, but these are reserved for actual measurements using standard techniques. Perviousness applies to the whole soil profile. Because of this, the perviousness class is determined by the least permeable layer in the soil "control section" (Canada Soil Survey Committee, 1978, p. 22). It is important to distinguish between soil drainage and perviousness. For example, a rapidly pervious soils could be receiving excessive seepage and thus be poorly drained.

a. Rapidly pervious - the capacity to transmit water vertically is so great that the soil will remain wet for no more than a few hours after thorough wetting. The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting.

b. Moderately pervious - the capacity to transmit water vertically is great enough that the soil will remain saturated for no more than a few days after thorough saturation. Most moderately pervious soils hold relatively large amounts of water against the force of gravity, and are considered good, physically, for rooting and supplying water to plants. Soil horizons may be granular, blocky, weakly platy or massive (but porous) if continuous conducting pores or cracks are present which do not close with wetting.

c. Slowly pervious - the potential to transmit water vertically is so slow that the horizon or the soil will remain saturated for a period of a week or more after thorough wetting. The soil may be massive, blocky or platy,

but connecting pores that conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry, close with wetting. Even in positions accessible to plant roots, roots are usually few or absent. When present, roots are localized along cracks.

APPENDIX B
STANDARD PERCOLATION TEST
(from Government of British Columbia, 1975)

(i) Percolation test holes shall be made at points and elevations selected as typical in the area of the proposed absorption field.

(ii) One of these test holes shall be dug at each end of the area of the absorption field. Further holes may be required, depending upon the nature of the soil, the results of the first tests and the size of the proposed absorption field.

(iii) Test holes shall be 25 cm (12 in)square and excavated to the proposed depth of the absorption field.

(iv) To make the percolation test more accurate, any smeared soil should be removed from the walls of the test holes.

(v) If the soil contains considerable amounts of silt and/or clay, the test holes must be presoaked before proceeding with the test. Presoaking is accomplished by keeping the hole filled with water for four hours or more. Proceed with the test immediately after presoaking.

(vi) To undertake the test, fill the test hole with water. When the water level is 12.5 cm (5 in) or less from the bottom of the hole, refill the hole to the top. No recording of time need be done for these two fillings.

(vii) When the water level, after the second filling (step vi) is 12.5 cm (5 in) or less from the bottom of the hole, add enough water to bring the depth of water to 15 cm (6 in) or more.

(viii) Observe the water level until it drops to the 15 cm (6 in) depth. At precisely 15 cm (6 in), commence timing. When the water level reaches the 12.5 cm (5 in) depth, stop timing. Record the time in minutes.

(ix) Repeat procedures (vii) and (viii) until the last two rates of fall do not vary more than 2 min/2.54 cm (2 min/in).

(x) Record and report all rates of fall in minutes per 2.54 cm (min per in).

(xi) Determine the percolation rate for the proposed sewage disposal system by averaging the slowest rate determined for each of the test holes.

(xii) Backfill the holes with the excavated soil and flag their locations.

APPENDIX C
RESTRICTIVE SOIL LAYERS

1. CEMENTED HORIZONS (from USDA, 1975 and CSSC, 1978)

Cementation of soil material refers to a brittle hard consistence caused by some cementing substance other than clay minerals, such as calcium carbonate, silica, or oxides or salts of iron and aluminum. Typically the cementation is altered little if any by moistening; the hardness and brittleness persist in the wet condition. Semi reversible cements, which generally resist moistening but soften under prolonged wetting, occur in some soils and give rise to soil layers having a cementation that is pronounced when dry but very weak when wet. Some layers cemented with calcium carbonate soften somewhat with wetting. Unless stated to the contrary, descriptions of cementation imply that the condition is altered little if any by wetting. If the cementation is greatly altered by moistening, it should be so stated. Cementation may be either continuous or discontinuous within a given horizon.

1. Weakly cemented: Cemented mass is brittle and hard but can be broken in the hands.

2. Strongly cemented: Cemented mass is brittle and harder than can be broken in the hand but is easily broken with a hammer.

3. Indurated: Very strongly cemented; brittle, does not soften under prolonged wetting, and is so extremely hard that for breakage a sharp blow with hammer is required; hammer generally rings as a result of the blow.

a. Duric horizon - a stongly cemented horizon that does not satisfy the criteria of a podzolic B horizon. Usually it has an abrupt upper boundary to an overlying podzolic B or to a Bm horizon and a diffuse lower boundary more than 0.5 m below. Cementation is usually strongest near the upper boundary, which occurs commonly at a depth of 40-80 cm from the mineral surface. The color of the duric horizon usually differs little from that of the moderately coarse textured to coarse textured parent material, and the structure is usually massive or very coarse platy. Air-dry clods of duric horizons do not slake when immersed in water, and moist clods at least 3 cm thick usually cannot be broken in the hands.

b. Ortstein horizon - a strongly cemented Bh, Bhf, or Bf horizon at least 3 cm thick that occurs in more than one-third of the exposed face of the pedon. Ortstein horizons are generally reddish brown to very dark reddish brown.

c. Placic horizon - a thin layer (commonly 5 mm or less thick) or a series of thin layers that are irregular or involuted, hard, impervious, often vitreous, and dark reddish brown to black. Placic horizons may be cemented by Fe, Al-organic complexes (Bhfc or Bfc), hydrated Fe oxides (Bgfc), or a mixture of Fe and Mn oxides.

d. Carbonate cementation - meets the definition of strongly cemented. The cemented layer is whitish in color and strongly effervesces when dilute HCl is added.

2. ACCUMULATION HORIZON (Bt)

A Bt horizon is one in which silicate clay has accumulated by illuviation. The most obvious field clues for recognition are a finer texture (see Appendix F) then the overlying or underlying horizons and the presence of coatings of

clay on the surfaces of pores, peds or individual grains. These coatings are usually brown in color and when they are present in quantities sufficient to restrict permeability, they are usually visible to the naked eye.

3. SLOWLY PERMEABLE PARENT MATERIALS (from E.L.U.C., 1976)

a. Morainal - The material transported beneath, beside, on, within and in front of a glacier; deposited directly from the glacier and not modified by any intermediate agent.

The deposits generally consist of well-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often in a matrix of sand, silt and clay. Non-compacted, coarse-textured, morainal deposits are an exception to the generally slow permeability.

b. Marine - Sediments that have settled from suspension in salt or brackish water bodies or that have accumulated at their margins through shoreline processes such as wave action and longshore drift.

The sediments consist of unconsolidated deposits of clay, silt, sand or gravel, well to moderately well-sorted, well-stratified to moderately-stratified, and in some places containing shells. Well-sorted and stratified gravelly marine deposits are an exception to the generally slow permeability.

c. Lacustrine - Sediments that have settled from suspension in bodies of standing fresh water or that have accumulated at their margins through wave action.

Lacustrine sediments commonly consist of stratified fine sand, silt and clay. Lacustrine deposits that contain only fine sand and silt may be moderately permeable.

APPENDIX D

FLOOD HAZARD CHARACTERISTICS

(Modified from Miles and Harding, 1980)

FLOOD HAZARD	LITTER COVER	OVERBANK DEPOSITS ETC.	FLUVIALLY TRANSPORTED DEBRIS	VEGETATION	TERRAIN HEIGHT	TERRAIN UNIT	ESTIMATED FLOOD FREQUENCY	SOIL CLASSIFICATION*
FREQUENT	No litter to a thin layer of non-decomposed material.	Presence of recent silt or sand deposits. Occasional scour holes.	Fluvially deposited logs and organic debris on channel banks. Occasionally debris in lower branches of trees.	None; or species typical of primary colonization; or species typical of wetlands.	Low lying areas.	Active Floodplains, or fans, includes active channels side channels, drainage channels and areas of marsh or swamp.	1-3 year return interval.	Orthic and Cumulic Regosols.
OCCASIONAL	Thin litter cover present ranging from recent to partly or completely decomposed material.	Silt and/or fine sand deposits interbedded with organic litter.	Fluvially deposited logs and organic debris may be present on the ground and in the lower branches of trees.	Mature trees. Possibly containing some species typical of primary colonization.	Areas of moderate elevation.	Area of valley flat disected by back, side and drainage channels.	Less than 50 year return interval.	Cumulic Regosols.
RARE	Thick litter cover, lower layer completely decomposed.	No evidence of "recent" overbank deposits.	Not present.	Mature trees.	Areas of higher elevation.	Areas of low terraces, fluvial fans, or colluvial deposits.	In the range of 50 to greater than 200 year return interval.	Cumulic Regosols; Brunisols.
NO HAZARD	Thick litter cover, lower layer completely decomposed. Soil profile development.	No evidence of "recent" overbank deposits.	Not present.	Mature trees.	Areas of higher elevation.	Areas of higher teraces, fluvial fans, colluvial deposits, etc. Usually adjacent to the valley walls.	This unit is unlikely to be flooded under the present hydrologic logic conditions.	Usually not Regosolic; will depend on area surveyed.

*for fluvial materials

APPENDIX E
SOIL DRAINAGE CLASSES
(from Walmsley et al., 1980)

The soil drainage classes are defined in terms of (i) actual moisture content in excess of field moisture capacity, and (ii) the extent of the period during which such excess water is present in the plant-root zone. It is recognized that permeability, level of groundwater, and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot be used generally as criteria for drainage classes.

It is further recognized that soil profile morphology, for example mottling, normally, but not always, reflects soil drainage. Although soil morphology may be a valuable field indication of drainage class, it should not be the overriding criterion. For example, a soil may exhibit the morphology of a poorly drained soil, but recent changes (either natural or artificial) may result in the soil being imperfectly drained. Some soils that are considered to be well drained are mottled during the early spring, but lack mottling throughout most of the growing season. Other well drained soils are permanently mottled because of the nature and the distribution of minerals within them. Therefore, soil drainage classes cannot be based solely on the presence or absence of mottling. Topographic position and vegetation, as well as other soil characteristics, are useful field criteria for assessing soil drainage classes.

The recommended definitions of the soil drainage classes are underlined. As a guide, additional comments under each class indicate some of the pertinent soil morphological features that are commonly, but not necessarily found.

a. Rapidly drained - The soil moisture content seldom exceeds field capacity in any horizon except immediately after water additions. Soils are free from any evidence of gleying or mottling throughout the profile. Rapidly drained soils often occur on steep slopes.

b. Well drained - The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper 1 m, but may be mottled below this depth.

c. Moderately well drained - The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are often faintly mottled in the lower B and C horizons or below a depth of 0.7 m. The Ae horizon, if present, may be faintly mottled in fine textured soils and in medium textured soils that have a slowly permeable layer below the A and B horizons. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.

d. Imperfectly drained - The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are often distinctly mottled in the B and C horizons; the Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well drained soil on similar parent material. Soils are generally "gleyed" subgroups of mineral soil orders.

e. Poorly drained - The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually strongly gleyed. Except in high chroma parent materials, the B, if present, and upper C horizons usually have matrix chromas of 3 or less, prominent mottling may occur throughout. Soils are generally in the Gleysol or Organic orders.

f. Very poorly drained - Free water remains at or within 30 cm of the surface most of the year. The soils are usually strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present within 30 cm or at depth in the profile. Soils are generally in the Gleysol or Organic orders; mineral soils are ususally a peaty phase.

APPENDIX F
SOIL TEXTURE
(from Walmsley et al., 1980)

Textural classes are defined in terms of the size distribution of primary mineral particles (2 mm dia. or less) as estimated by sieve and sedimentaton analysis, or field estimation. The basic textural classes are indicated in Figure 5, in terms of percent clay (finer than 0.002 mm), silt (0.002 to 0.05 mm), and sand (0.05 - 2.0 mm), with the code symbols indicated in the textural triangle.

If necessary, the lab can be requested to further separate any of the sand, silt, or clay sizes to further refine the soil texture classes as follows (or in some other way):

Name of Separate	Diameter (mm)	Symbol
Very coarse sand	2.0-1.0	vcs
Coarse sand	1.0-0.5	cs
Medium sand	0.5-0.25	ms
Fine sand	0.25-0.10	fs
Very fine sand	0.10-0.05	vfs
Silt	0.05-0.002	si
Clay	<0.002	c
Fine clay	<0.0002	fc

Please note: for silt, the soil notation is "si", while the terrain notation is "ȿ".

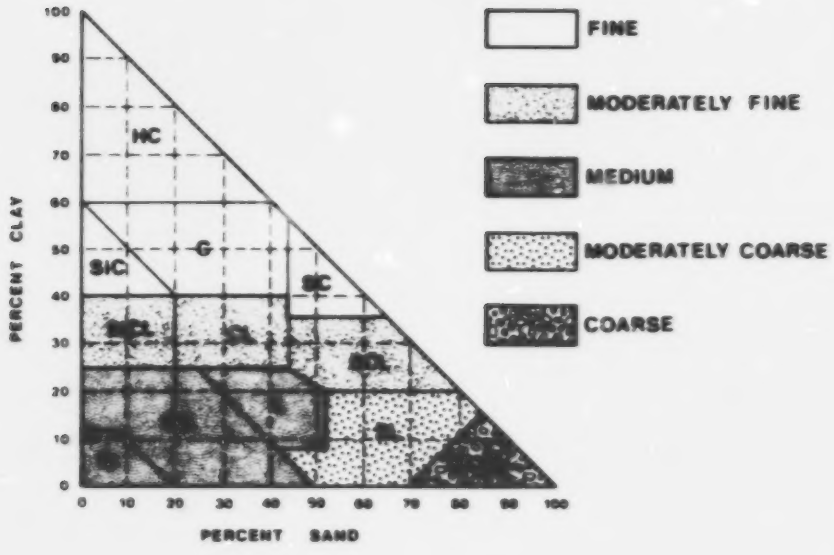

Figure 5. Soil textural triangle.

Soil Texture Classes:

Sands - 85% or more sand; the percentage of silt, plus 1.5 times the percentage of clay, does not exceed 15.

Coarse sand - 25% or more very coarse and coarse sand, and less than 50% any other one grade of sand.

Medium sand - 25% or more very coarse, coarse, and medium sand, and less than 50% fine or very fine sand.

Fine sand - 50% or more fine sand, or less than 25% very coarse, coarse and medium sand and less than 50% very fine sand.

Very fine sand - 50% or more very fine sand.

Loamy Sand - upper limit of sand is 85-90%, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; lower limit of sand is 70-85%, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Sandy Loam - contains either 20% clay or less, with the percentage of silt plus twice the percentage of clay exceeding 30, and 52% or more sand, or less than 7% clay, less than 50% silt, and 43-52% sand.

Loam - contains 7-27% clay, 28-50% silt, and less than 52% sand.

Silt Loam - Contains 50% or more silt and 12-27% clay, or 50-80% silt and less than 12% clay.

Silt - contains 80% or more silt and less than 12% clay.

Sandy Clay Loam - contains 20-35% clay, less than 28% silt, and 45% or more sand.

Clay Loam - contains 27-40% clay and 20-45% sand.

Silty Clay Loam - contains 27-40% clay and less than 20% sand.

Sandy Clay - contains 35% or more clay and 45% or more sand.

Silty Clay - contains 40% or more clay and 40% or more silt.

Clay - contains 40% or more clay, less than 45% sand, and less than 40% silt.

Heavy Clay - contains more than 60% clay.

APPENDIX G

COMPARISON OF SOIL (USDA), UNIFIED & AASHO TEXTURES

(from USDA, 1971)

USDA Texture Class and Symbol	Unified Symbol	AASHO Symbol	Soil Properties Related to Classifications
Clay; silty clay "c"; "sic"	CH MH CL	A-7 A-7 A-7	High shrink-swell clays. Mica, iron oxide, kaolinitic clays. Low LL. Generally <45 pct clay.
Silty clay loam "sicl"	CL ML-CL CH MH	A-7 A-7 A-7 A-7	Low LL. Plastic. (A-6 if clay <30 pct). Low LL. Mod. plastic. (A-6 if clay <30 pct). High LL. High shrink-swell clays. High LL. Mica, iron oxide, kaolinitic.
Clay loam "cl"	CL ML-CL CH MH	A-6 or A-7 A-6 A-7 A-7	Low LL. Plastic. Low LL. Moderately plastic. High LL. High shrink-swell clays. High LL. Mica, iron oxide, kaolinitic.
Loam "l"	ML-CL CL ML	A-4 A-6 A-4	Moderately plastic (A-6 if clay >21 pct.) Plastic (A-4 if clay <22 pct). Low plasticity (A-7 if clay >21 pct).
Silt loam "sil"	ML-CL ML CL	A-4 A-4 A-6	Moderately plastic (A-6 if clay >21 pct). Low plasticity (A-7 if clay >21 pct). Plastic.
Silt - "si"	ML	A-4	Low plasticity.
Sandy clay "sc"	CL SC	A-7 A-7	Fines >50 pct. Fines 50 pct or less.
Sandy clay loam "scl"	SC SC CL	A-6 A-2-6 A-6	Plastic. Fines 36-50 pct. Plastic. Fines 35 pct or less. Plastic. Fines >50 pct.
Sandy loam "sl"	SM SC SM-SC	A-2-4 or A-4 A-2-4 A-2-4	Low plasticity. Plastic. Moderately plastic.
Fine sandy loam "fsl"	SM ML ML-CL SM-SC	A-4 A-4 A-4 A-4	Nonplastic. Fines 50 pct or less. Nonplastic. Fines >50 pct. Moderately plastic. Fines >50 pct. Moderately plastic. Fines 50 pct or less.
Very fine sandy loam "vfsl"	ML-CL ML	A-4 A-4	Moderately plastic. Low plasticity.
Loamy sands "ls"; "lfs" "lvfs"	SM SM-SC SM ML	A-2-4 A-2-4 A-4 A-4	Nonplastic. Fines 35 pct or less. Moderately plastic. Fines 35 pct or less. Low plasticity. Fines >35 pct. Little or no plasticity.
Sand; fine sand "s"; "fs"	SP-SM SM SP	A-3 A-2-4 A-3	Fines approx. 5-10 pct. Fines approx. >10 pct. Fines <5 pct.
Very fine sand "vfs"	SM ML	A-4 A-4	Low plasticity. Little or no plasticity.

USDA Texture Class and Symbol	Unified Symbol	AASHO Symbol	Soil Properties Related to Classifications
Coarse sand "cs"	SP; GW	A-1	Fines >5 pct.
	SP-SM	A-1	Fines 5-12 pct.
	SM	A-1	Fines 13-25 pct.
	SM	A-2-4	Fines >25 pct.
Gravel, "G" 50 pct passes No.200 50 pct of coarse passes No. 4 sieve	GP;GW	A-1	Fines <5 pct.
	GM or GC	A-1	Fines 5-25 pct.
	GM or GC	A-2	Fines 26-35 pct.
	GM	A-4	Fines >35 pct.
	GC	A-6	Fines >35 pct.

APPENDIX H

TEXTURE OF SURFICAL MATERIALS

(Modified from Wentworth Scale, E. L. U. C. Secretariat, 1976)

Texture

Texture refers to the size, roundness and sorting of particles in clastic sediments, and the proportional fibre content of organic sediments.

Symbol	Name	Size (mm)	Other Characteristics
Clastic	Sediments		
b	bouldery	>256	rounded & subrounded particles — includes a minor amount of finer interstitial material and sand matrix
k	cobbly	64-256	rounded & subrounded particles — includes a minor amount of finer interstitial material and sand matrix
p	pebbly	2-64	rounded & subrounded particles — includes a minor amount of finer interstitial material and sand matrix
g	gravelly		a mixture of pebbles, cobbles and possibly boulders in a sand matrix
s	sandy	0.625-2	
ś	silty	.004-.0625	
c	clayey	<.004	
f	fines		a mixture of clay, silt and possibly fine sand
r	rubbly	2-256	angular and subangular particles — includes a minor amount of finer interstitial material
a	blocky	>256	large angular and sub-angular particles, commonly ranging up to 2 m diameter, with rubble and finer interstitial material
Organic	Sediments		
e	fibric	--	the least decomposed of all organic materials: there is a large amount of well-preserved fibre that is readily identifiable as to botanical origin.
m	mesic	--	organic material in an intermediate stage of decomposition: an intermediate amount of fibre is present that can be identified as to botanical origin.
h	humic	--	highly decomposed organic material: there is a small amount of fibre present that can be identified as to botanical origin.

Explanatory Notes

1. The absence of a textural term from a unit symbol indicates that texture of the material was not observed in the field and cannot be reliably interpreted from air photos or from a knowledge of the bedrock geology.

2. Where two textural terms are used together, they are written in order to increasing importance. e.g. śs is silty sand, sg is sandy gravel.

APPENDIX I
FIELD DETERMINATION OF TEXTURE (HAND-TEXTURING)
(from Walmsley et al., 1980)

The determination of soil texture "by feel" requires a great deal of practice and comparison with standards having known particle size distributions. It depends on the ability to feel sand grains at one extreme of particle size and plasticity and stickiness of clays at the other. Ability to feel sand grains is a uniform criterion in all soils, but different clay minerals may feel differently. Consequently, standards of "feel" established in one region may not apply in others where clay types are different. Montmorillonite clays are much more plastic and sticky than illite clays. Oxide clays are much less plastic and sticky than others. In volcanic tropical areas (e.g. Hawaii), soils containing 90% clay "feel" like silty clay loams (27 to 40% clay) of British Columbia. Other variables affecting the feel of a given texture class are particle size differences (coarse versus fine clay, for example), the dominant exchangeable cation, and organic matter content. Criteria for British Columbia soils in general were used in the following key.

Frequently clay particles are grouped into small hard aggregates that give a feel of sand when dry. The soil must be moistened and rubbed vigorously between the fingers to release all of the primary particles.

For determination of texture by feel, the soil should be moist but not saturated (at moisture levels slightly above field capacity). Proper moisture content is the most difficult factor to judge. Generally coherent soil should be as wet as necessary to permit it to be rolled between the palms of the hands and pressed into a "ribbon" between thumb and forefinger leaving moisture on the skin when handled, but without sticking to the fingers. As the soil is handled, it loses moisture and becomes less and less pliable. One should start at the maximum moisture the soil will hold without sticking to the fingers and note the change as it dries.

Surveyors must remember that horizons of the same soil textural class, but varying in particle size distribution, may have a different feel (and different physical properties).

Key to General Texture Groups

A Rub the moist soil between thumb and forefinger. If you can feel individual sand grains distinctly as a major part of the mass, proceed to A1. If not proceed to B.

A1 Press the dry soil hard between thumb and forefinger. If it forms a cast that holds together slightly, proceed to A2. If the cast falls apart when pressure is released, it is probably coarse textured (sand or loamy sand). Check this by pressing when moist. If the cast formed can be transferred from one hand to another, proceed to A2. If it can not, it is coarse (sand, loamy sand).

A2 If the cast formed of dry soil can be transferred from one hand to another, proceed to A3. If it cannot, it is probably moderately coarse textured (sandy loam; fine sandy loam). Check this moist. If the cast of moist soil can be handled readily without breaking, proceed to A3. If it can be tansferred form one hand to the other, but cannot readily be picked up intact, it is moderately coarse (sandy loam; fine sandy loam).

A3 Squeeze the fully moist (not wet) soil between thumb and forefinger with a shearing stress. If the soil forms a thin smooth "ribbon" that will bear its own weight, proceed to A4. If it forms a rough "ribbon" that breaks under its own weight it is medium textured (loam).

A4 Roll the fully moist soil into a worm-like roll about 6mm (1/4 inch) in diameter between the palms of the hands. If the roll can bear its own weight when it is flexed (shake while holding one end), proceed to A5. If the roll breaks easily when flexed, it is moderatley fine (clay loam).

A5 If the roll does not break when flexed, it is fine textured (sandy clay).

B Sand grains cannot be felt distinctly as a major part of the mass (one may feel a few sand grains). Proceed to B1.

B1 Shear the fully moist (but not wet) soil between thumb and forefinger. If it forms a slick unbroken "ribbon" proceed to B2. If it forms a broken rough ribbon it is medium textured (silt, silt loam or very fine sandy loam).

(By carefully feeling for slight abrasiveness the very fine sandy loam can be detected. Pulverized when dry, silt feels soft and floury; silt loam has a similar feeling but sand grains may also be apparent. Very moist silt feels soapy. Silt has a gritty feel when chewed between the teeth).

B2 Roll the fully moist soil between palms of the hands. If the roll bears its own weight readily when flexed, proceed to B3. If it breaks, it is moderately fine (silty clay loam).

B3 If the roll bears its own weight when flexed, it is fine textured (clay or silty clay).

(Most clay is quite plastic and usually sticky when wet. Clay is not gritty when chewed between the teeth. Some fine clays very high in colloids are friable and lack plasticity in all moisture conditions).

APPENDIX J

SOIL STRUCTURE

TYPES, KINDS AND CLASSES OF SOIL STRUCTURE

(from Walmsley et al., 1980)

TYPE	KIND	CLASS	SIZE
Blocklike-soil particles arranged around a point and bounded by flat or rounded surfaces	Angular blocky (ABK): peds bounded by flattened, rectangular faces intersecting at relatively sharp angles	VF: very fine angular blocky	<5
		F: fine angular blocky	5-10
		M: medium angular blocky	10-20
		C: coarse angular blocky	20-50
		VC: very coarse angular blocky	>50
	Subangular blocky (SBK): peds bounded by slightly rounded, subrectangular faces with vertices[2] of their intersections mostly subrounded	VF: very fine subangular blocky	<5
		F: fine subangular blocky	5-10
		M: medium subangular blocky	10-20
		C: coarse subangular blocky	20-50
		VC: very coarse subangular blocky	>50
	Granular (GR): Spheroidal peds bounded by curved or very irregular faces that do not adjoin those of adjacent peds	VF: very fine granular	<1
		F: fine granular	1-2
		M: medium granular	2-5
		C: coarse granular	5-10
		VC: very coarse granular	>10
Platelike-soil particles arranged around a horizontal plane and and generally bounded by relatively flat horizontal surfaces	Platy (PL): Peds flat or platelike; horizontal planes more or less developed	VF: very fine platy	<1
		F: fine platy	1-2
		M: medium platy	2-5
		C: coarse platy	5-10
		VC: very coarse platy	>10
Prismlike-soil particles arranged around a vertical axis and bounded by relatively flat vertical surfaces	Prismatic (PR): Vertical faces of peds well defined and vertices[2] angular (edges sharp); prism tops essentially flat	VF: very fine prismatic	<10
		F: fine prismatic	10-20
		M: medium prismatic	20-50
		C: coarse prismatic	50-100
		VC: very coarse prismatic	>100
	Columnar (COL): Vertical edges near top of columns not sharp (vertices[2] subrounded); column tops flat, rounded, or irregular	VF: very fine columnar	<10
		F: fine columnar	10-20
		M: medium columnar	20-50
		C: coarse columnar	50-100
		VC: very coarse	>100
Structureless-no observable aggregation of primary particles or no definite orderly arrangement around natural lines of weakness	Single grained (SGR): loose, incoherent mass of individual primary particles, as in sands		
	Massive (MA): amorphous; a coherent mass showing no evidence of any distinct arrangement of soil particles; separates into clusters of particles, not peds		
Cloddy (CDY): not a structure; used to indicate the condition of some ploughed surfaces; grade, class, and shape too varied to be described in standard terms.			

1. The size limits refer to measurements in the smallest dimension of platy, prismatic, and columnar peds and to the largest of the nearly equal dimensions of blocky and granular peds.
2. Definition of vertex (plural, vertices): The intersection of two planes of a geometrical figure.

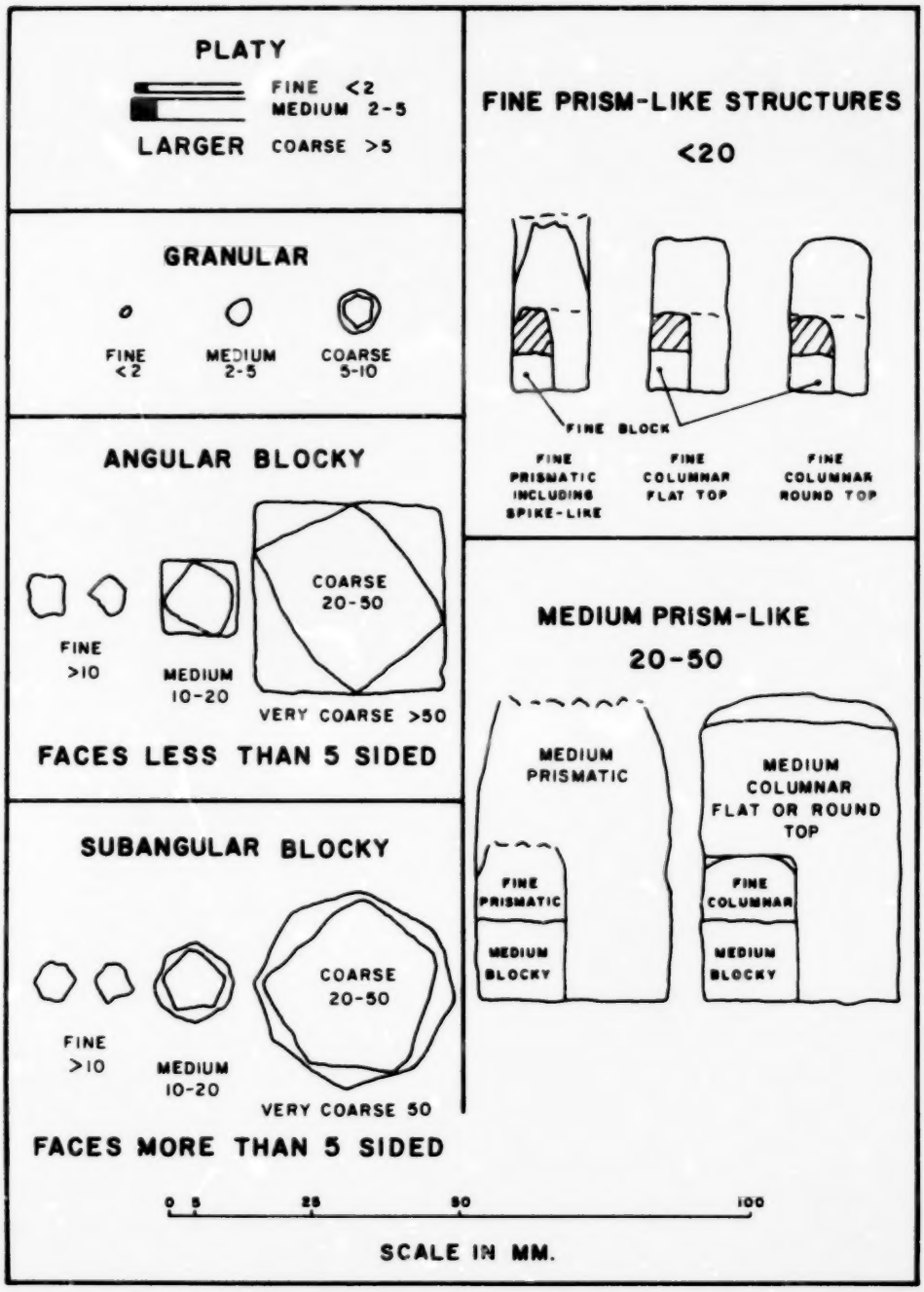

Figure 6. Diagrammatic representation of soil structure.